Table 3.2.4.9 Net Calorific Value of Fuel

Fuel	Unit	Mj/Unit
Natural Gas	scf	1.02
LPG	Litre	26.62
Gasoline	Litre	31.48
Kerosene	Litre	34.53
Diesel	Litre	36.42
Fuel Oil	Litre	39.77
Coal	kg	26.37
Lignite	kg	14.80 (1)
Fuel Wood	kg	15.99
Charcoal	kg	28.88
Paddy Husk	kg	14.40
Bagasse	kg	7.53

Source: DEDP/Thailand Energy Situation 2000
(1) Average value of those of Li, Krabi and Chae Khon

3.2.5 SOx Emission in the Whole of Thailand

3.2.5.1 SOx Emission by Sector

Sectoral SOx emission in the whole of Thailand in 2000 is given in Table 3.2.5.1 and Figure 3.2.5.1. The annual total SOx emission in Thailand in 2000 is 326 thousand tons. Among them, the manufacturing sector accounts for 54.3%, followed by the power sector (33.5%) and refinery (10.3%). The total of these three sectors' share is 98.1%.

Table 3.2.5.1 Annual SOx Emission by Sector in 2000

Sector	SOx Emission (ton/Y)	Share (%)
Power	109,415	33.5
Agriculture	2,283	0.7
Mining	57	0.0
Manufacturing	177,085	54.3
Construction	896	0.3
Residential and Commercial	2,827	0.9
Refinery	33,712	10.3
Total	326,275	100.0

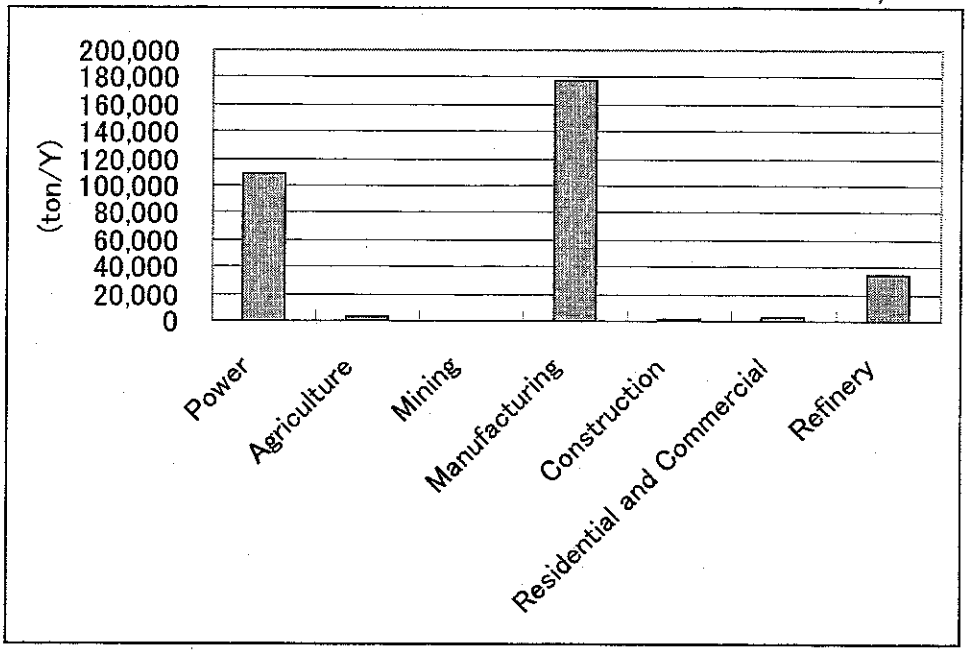

Figure 3.2.5.1 Sectoral Share in the Total SOx Emission in Thailand in 2000

3.2.5.2 SOx Emission of Point and Area Sources

Annual SOx emission by point sources in 2000 is shown in Table 3.2.5.2 and Figure 3.2.5.1. EGAT Power Plants and refineries emit 102 thousand tons/Y and 34 thousand tons/Y respectively.

Table 3.2.5.2 Annual SOx Emission by Point Sources in 2000

		(ton/Y)	% share
Power Plant	EGAT	102,121	41.8
	IPP	1,269	0.5
	SPP	6,026	2.5
	Total	109,415	44.8
Refinery		33,712	13.8
Cement plant		16,642	6.8
Other		84,478	34.6
Total		244,247	100.0

The annual SOx emission from point and area sources in 2000 is summarized in Table 3.2.5.3. About 75% of the total SOx emission is covered by point sources.

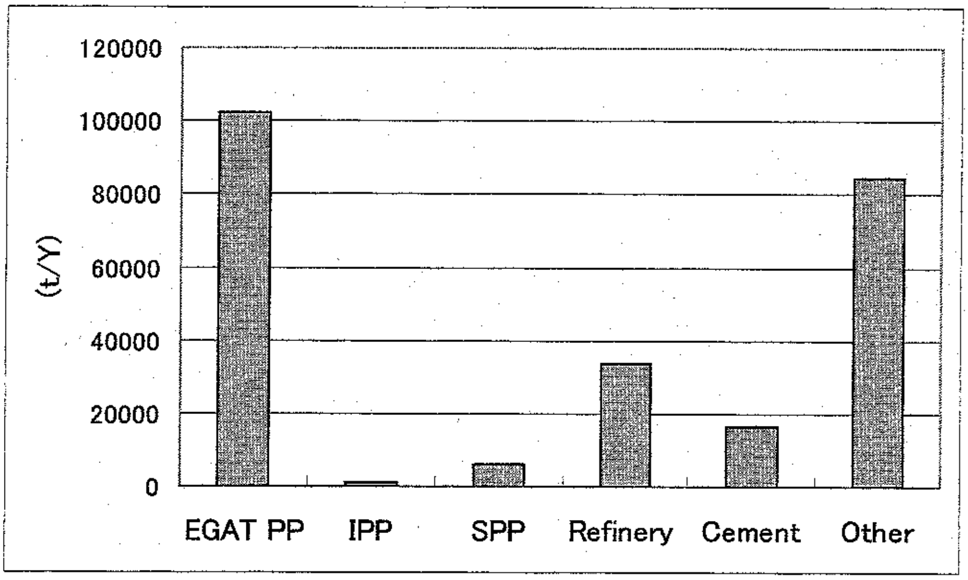

Figure 3.2.5.2 Annual SOx Emission by Point Source in 2000

Table 3.2.5.3 The annual SOx Emission from Point and Area Sources in 2000

	SOx Emission (ton/Y)	Share (%)
Point	244,246	74.9
Area	82,028	25.1
Total	326,275	100.0

3.2.5.3 SOx Emission by Province

The annual SOx emission by province is summarized in Table 3.2.5.4 and Figure 3.2.5.3. Provinces emitting more than 10,000 tons in 2000 are shown in Table 3.2.5.5 and Figure 3.2.5.4. Samut Prakan emits the largest amount of SOx at 45.7 thousand tons, followed by Lampang (40.2 thousand tons). These ten provinces account for 81% of the total SOx emission in Thailand in 2000.

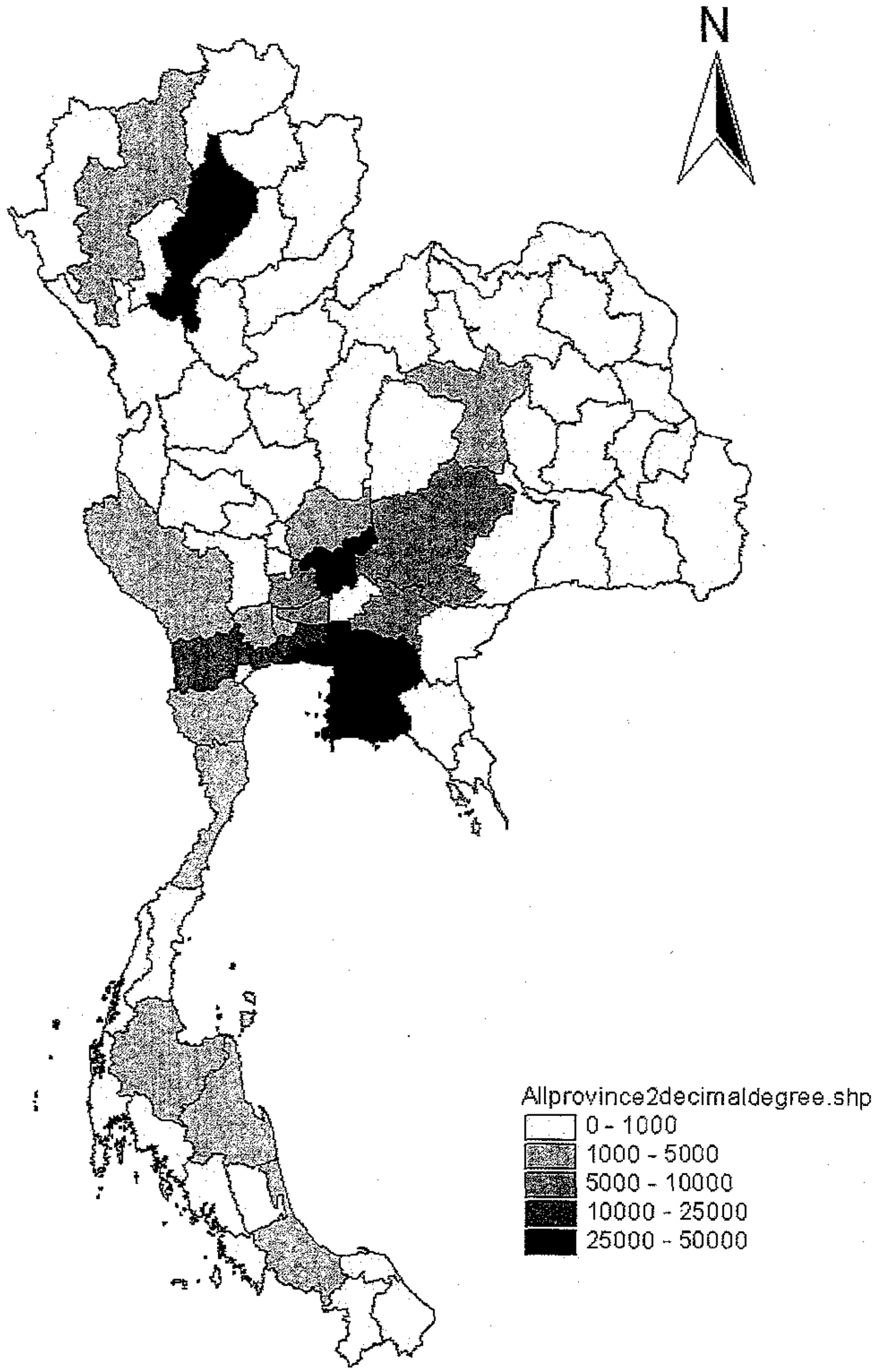

Figure 3.2.5.3 Distribution of Provincial SOx Emission in 2000

Table 3.2.5.4 (1) SOx Emission by Province in 2000

(ton/Y)

No.	Province	Power	Refinery	Manufacturing			Other	Total
				Cement	Other	Total		
	BMR	27,534	566		71,848	71,848	780	100,728
1	Bangkok	1	566		15,902	15,902	445	16,914
2	Nonthaburi	2,756			2,914	2,914	46	5,715
3	Pathum Thani	0			13,852	13,852	35	13,887
4	Samut Prakan	24,777			20,843	20,843	93	45,714
5	Samut Sakhon	0			13,217	13,217	82	13,298
6	Nakhon Pathom	0			5,120	5,120	79	5,200
	Central	11,199		12,113	39,086	51,199	681	63,079
7	Kanchanaburi				3,206	3,206	81	3,287
8	Chai Nat	1			29	29	48	78
9	Prachuap Khiri Khan				2,600	2,600	58	2,658
10	Phetchaburi			281	768	1,048	43	1,091
11	Ratchaburi	9,364		135	4,896	5,031	85	14,479
12	Lop Buri	4			4,321	4,321	78	4,403
13	Samut Songkhram				35	35	17	52
14	Saraburi	1,615		11,697	16,954	28,651	56	30,322
15	Sing Buri				220	220	20	240
16	Suphan Buri	6			104	104	104	214
17	Ayutthaya	210			5,127	5,127	66	5,402
18	Ang Thong				827	827	25	852
	Northern Region	37,281	3	2,957	4,013	6,970	1,144	45,399
	upper part	37,260	3	2,320	2,726	5,046	567	42,877
19	Chiang Rai				300	300	94	394
20	Chiang Mai	333	3		716	716	128	1,179
21	Nan				147	147	65	211
22	Phayao				110	110	40	149
23	Phrae				143	143	48	191
24	Mae Hong Son						25	26
25	Lampang	36,928		2,320	947	3,267	70	40,265
26	Lamphun				365	365	98	462
	lower part	21		637	1,287	1,924	577	2,522
27	Kamphaeng Phet	12			535	535	95	642
28	Tak				290	290	59	349
29	Nakhon Sawan	7		637	235	872	76	955
30	Phichit				14	14	45	59
31	Phitsanulok				42	42	90	132
32	Phetchabun				55	55	67	121
33	Sukhothai				51	51	60	111
34	Uttaradit	2			30	30	35	68
35	Uthai Thani				35	35	49	84
	Northeastern Region	945			8,827	8,827	1,713	11,486
	upper part	929			3,492	3,492	853	5,275
36	Kalasin				206	206	68	273
37	Khon Kaen	929			2,735	2,735	154	3,819
38	Nakhon Phanom				17	17	54	71
39	Maha Sarakham				42	42	87	129
40	Mukdahan				8	8	48	56
41	Roi Et				11	11	84	95
42	Loei				43	43	53	96
43	Sakon Nakhon				36	36	77	113
44	Nong Khai				160	160	56	216
45	Nong Bua Lam Phu				24	24	65	89
46	Udon Thani				209	209	108	316
	lower part	16			5,335	5,335	860	6,211
47	Chaiyaphum	4			234	234	106	344
48	Nakhon Ratchasima	12			4,859	4,859	174	5,045
49	Buri Ram				37	37	107	144
50	Yasothon				17	17	70	86
51	Si Sa Ket				21	21	116	138
52	Surin				33	33	91	124
53	Amnat Charoen				7	7	54	60
54	Ubon Ratchathani				128	128	141	270

Table 3.2.5.4 (2) SOx Emission by Province in 2000

(ton/Y)

No.	Province	Power	Refinery	Manufacturing			Other	Total
				Cement	Other	Total		
	Southern Region	1,531		1,572	6,851	8,423	1,247	11,201
	upper part	1,531		1,572	2,336	3,907	612	6,050
55	Krabi				50	50	71	121
56	Chumphon				179	179	67	246
57	Nakhon Si Thammarat	1,171		1,572	662	2,234	194	3,599
58	Phangnga				89	89	57	147
59	Phuket				258	258	35	293
60	Ranong				46	46	36	81
61	Surat Thani	359			1,052	1,052	153	1,564
	lower part				4,515	4,515	636	5,151
62	Trang				16	16	107	123
63	Narathiwat				67	67	79	146
64	Pattani				200	200	93	292
65	Phathalung				3	3	51	54
66	Yala				37	37	56	94
67	Songkhla				4,174	4,174	198	4,372
68	Satun				20	20	51	70
	Eastern Region	30,924	33,143		29,818	29,818	497	94,383
69	Chanthaburi				172	172	53	224
70	Chachoengsao	26,954			2,154	2,154	76	29,184
71	Chon Buri	22	15,700		13,611	13,611	122	29,455
72	Trat				4	4	34	37
73	Nakhon Nayok				25	25	23	48
74	Prachin Buri	2,508			2,706	2,706	45	5,259
75	Rayong	1,440	17,444		11,063	11,063	93	30,039
76	Sa Kaeo				84	84	51	135
	Total	109,415	33,712	16,642	160,443	177,085	6,063	326,275

Table 3.2.5.5 Provinces Emitting More Than 10,000 tons of SOx in 2000

	Province	SOx (ton/Y)
1	Samut Prakan	45,714
2	Lampang	40,265
3	Saraburi	30,322
4	Rayong	30,039
5	Chon Buri	29,455
6	Chachoengsao	29,184
7	Bangkok	16,914
8	Ratchaburi	14,479
9	Pathum Thani	13,887
10	Samut Sakhon	13,298
	Total	263,558

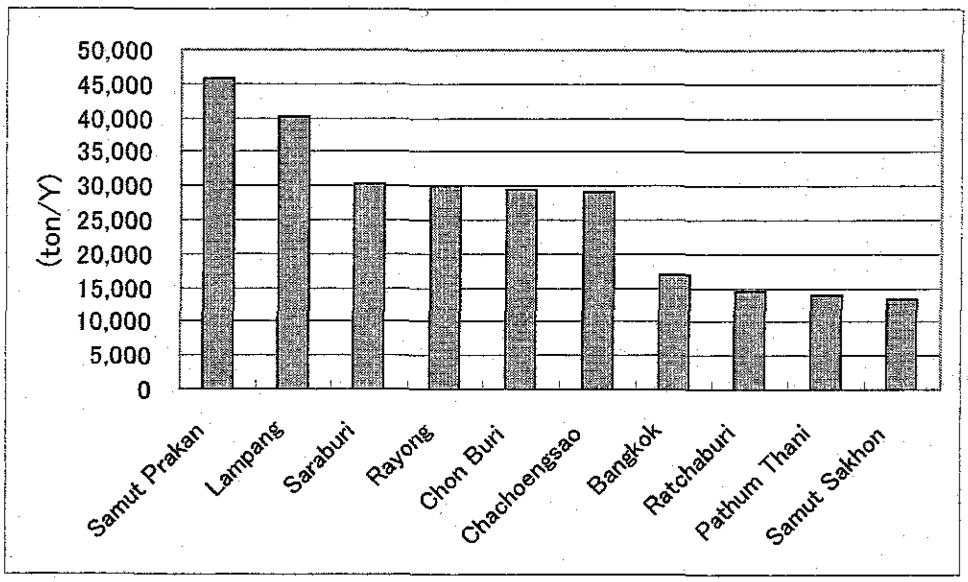

Figure 3.2.5.4 Provinces emitting more than 10 thousand tons of SOx in 2000

3.2.5.4 SOx Emission by Region

SOx emission by region is shown in Table 3.2.5.6 and Figure 3.2.5.5. The BMR and Eastern Region emit 100.7 thousand tons of SOx (30,9%) and 94.3 thousand tons of SOx (28.9%) respectively.

Table 3.2.5.6 Regional SOx Emission in 2000

Region	SOx Emission (ton/Y)	Share (%)
BMR	100,728	30.9
Central	63,079	19.3
Northern	45,399	13.9
Northeastern	11,486	3.5
Southern	11,201	3.4
Eastern	94,383	28.9
Total	326,275	100.0

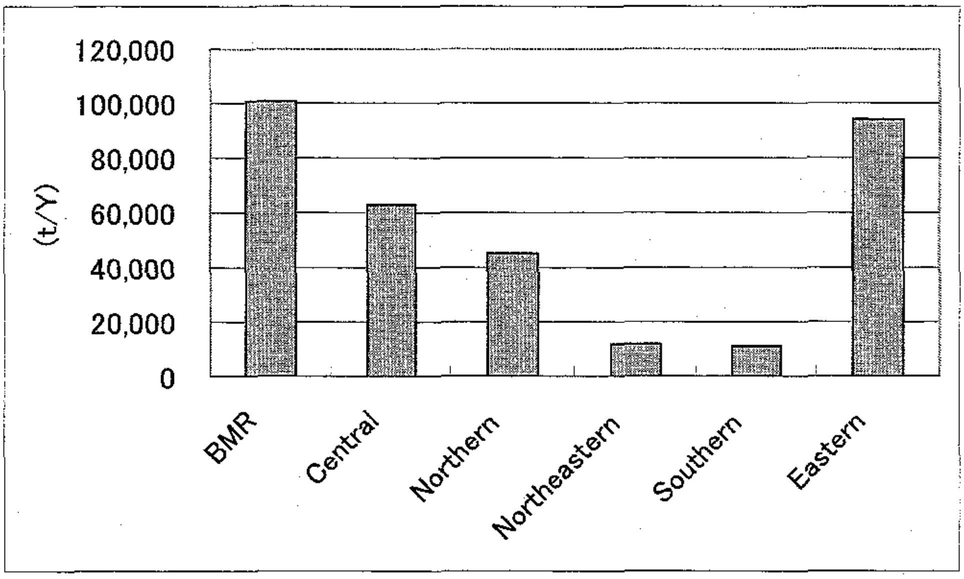

Figure 3.2.5.5 Regional SOx Emission in 2000

3.2.5.5 Comparison with Existing SOx Estimation of Thailand

Three estimates were compared: those by the JICA Study Team, DEDP and the Trace-P project (Table 3.2.5.7). The major difference between DEDP's estimation and that of the JICA Study Team is that the former estimation for the power plant is 200,000 tons higher than that of the Study Team. The estimation by the Trace-P project is about twice as high as that of the JICA Study Team.

Table 3.2.5.7 Comparison with Other Estimation for 2000

	Power plant	Industry	Residential	Others	Total
JICA Team	109,415	210,797	2,827	3,236	326,275
DEDP (1)	341,000	220,000	1,000	4,000	566,000
Trace-P project (2)	400,010	488,750	22,310		911,070

Note (1) : DEDP/Thailand Energy situation 2000/

(2): http:/www.cgrer.uiowa.edu./ACESS/EMISSION_DATA/ED_index.htm

3.2.6 SOx and NOx Emission in the BMR

3.2.6.1 SOx

Table 3.2.6.1 and Figure 3.2.6.1 show the annual emission of SOx emission in the BMR in 2000. Annual total emission of SOx in 2000 is 100.7 thousand tons, of which Samut Prakan accounts for 45.4 % (45.7 thousand tons) followed by Bangkok (16.9 %, 16.8 thousand tons) and Pathum Thani (13.8 %, 13.9 thousand tons).

Table 3.2.6.1 Annual SOx Emission in the BMR in 2000

(Uint: ton/Y)

	Point				Area						
Province	Power plants	Refinery	Other	Sub-total	Agriculture	Mining	Construction	Resi. & Comm.	Sub-otal	Total	% share
Bangkok	1	566	15,902	16,469	42		318	86	445	16,914	16.8
Nonthaburi	2,756		2,914	5,669	9		24	13	46	5,715	5.7
Pathum Thani			13,852	13,852	13	0.0	12	10	35	13,887	13.8
Samut Prakan	24,777		20,843	45,620	60		18	15	93	45,714	45.4
Samut Sakhon			13,217	13,217	50	0.7	9	22	82	13,298	13.2
Nakhon Pathom			5,120	5,120	31	0.0	9	39	79	5,200	5.2
Total	27,534	566	71,848	99,948	205	0.8	390	184	780	100,728	100.0

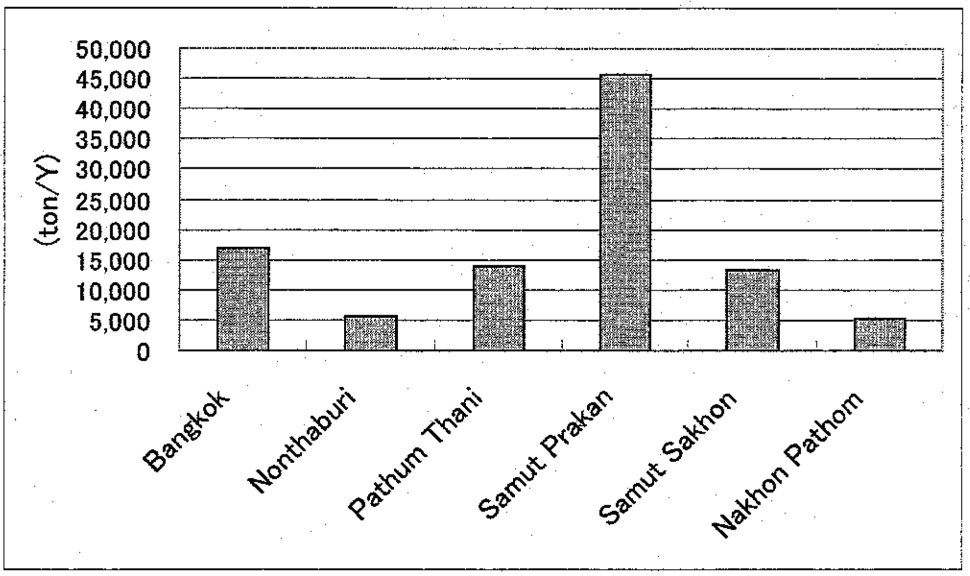

Figure 3.2.6.1 Provincial SOx Emission in the BMR in 2000

3.2.6.2 NOx

Annual NOx emission in the BMR is shown in Table 3.2.6.2 and Figure 3.2.6.2. Total NOx emission in the BMR in 2000 is 67.0 thousand tons, of which Samut Prakan accounts for 42.2 %

followed by Bangkok (18.0 %) and Pathum Thani (15.2 %). Each provincial share of SOx emission is almost the same as that of NOx.

Table 3.2.6.2 Annual NOx Emission in the BMR in 2000

(Uint: ton/Y)

Province	Point				Area					Total	% share
	Power plants	Refinery	Other	Sub-total	Agriculture	Mining	Construction	Resi. & Comm.	Sub-otal		
Bangkok	93	787	5,332	6,211	2,168		1,995	818	4,980	11,191	18.1
Nonthaburi	301		1,092	1,393	1,587		56	85	1,728	3,121	5.0
Pathum Thani			8,552	8,552	449		150	122	721	9,273	15.0
Samut Prakan	18,579		7,489	26,068	683	5	73	95	856	26,924	43.5
Samut Sakhon			3,324	3,324	3,083		116	143	3,342	6,666	10.8
Nakhon Pathom			2,002	2,002	2,585		58	47	2,689	4,691	7.6
Total	18,973	787	27,791	47,551	10,554	5	2,448	1,310	14,317	61,868	100.0

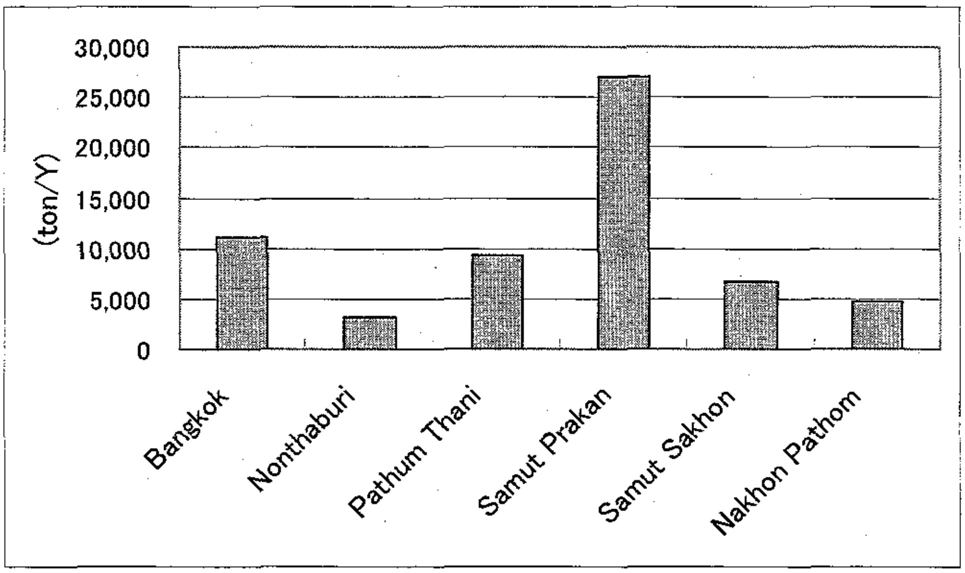

Figure 3.2.6.2 Annual NOx Emission in the BMR in 2000

3.3 Inventory of the Year 2011

3.3.1 Basic Data Collected and Used

To develop the inventory for the year 2011, the following data were collected and used (Table 3.3.1.1). EIA reports on the sources which are to start operation between 2000 and 2011 were collected (Table 3.3.1.2).

Table 3.3.1.1 Data Collected and Used

Power	EGAT OEPP	Forecasts in 2011 EIA Reports
Agriculture	TDRI TDRI DEDP oil NESDB	Forecast of growth rate of gross domestic product Forecast of growth rate of gross regional product Fuel consumption between 1982 and 2000 Gross domestic product between 1982 and 2000
Mining	TDRI TDRI DEDP oil NESDB	Forecast of growth rate of gross domestic product Forecast of growth rate of gross regional product Fuel consumption between 1982 and 2000 Gross domestic product between 1982 and 2000
Manufacturing	TDRI TDRI DEDP oil NESDB OEPP	Forecast of growth rate of gross domestic product Forecast of growth rate of gross regional product Fuel consumption between 1982 and 2000 Gross domestic product between 1982 and 2000 EIA Reports
Construction	TDRI TDRI DEDP oil NESDB	Forecast of growth rate of gross domestic product Forecast of growth rate of gross regional product Fuel consumption between 1982 and 2000 Gross domestic product between 1982 and 2000
Residential & Commercial	TDRI TDRI DEDP oil NESDB	Forecast of growth rate of gross domestic product Forecast of growth rate of gross regional product Fuel consumption between 1982 and 2000 Gross domestic product between 1982 and 2000
All sectors other than power sector	NEPO	Energy saving

Table 3.3.1.2 Collected EIA Reports

Sector	Sub Division	Number of Reports	Note
Power	EGAT	1	Expansion
	IPP	5	New
	SPP	4	Expansion
Manufacturing	Petrochemical	1	New
		3	Expansion
	Cement	3	Fuel conversion
	Pulp and paper	2	Expansion
	Steel	1	New
		1	Expansion
Total		21	

3.3.2 Method for the Development of the Stationary Source Inventory of the Year 2011

3.3.2.1 Basic Assumption

1) Adoption of sector-wise approach

The stationary source inventory of the year 2011 was developed based on the collected data and information on the future sources and the inventory of the Base Year. Due to differences in the data and information between 6 sectors and their share to total SOx (and NOx) emission, a sector-wise approach was taken.

2) Power sector

According to the forecast by EGAT, in the power sector, repowering and fuel diversification are planned. So, fuel conversion and energy saving are regarded to be taken into consideration for the power sector.

3) Other Sectors

(1) Fuel conversion

Since no adequate information was obtained for other sectors other than the power sector, fuel conversion was not considered for the other 5 sectors (agriculture, mining, manufacturing, construction, and residential and commercial sectors).

(2) Energy saving

NEPO has a plan of energy saving at an annual rate of 0.2% (Energy Conservation Program and Guidelines, Criteria, Conditions and Expenditure Priorities of the Energy Conservation Fund, During the Fiscal period 2000-2004). Therefore, a total energy saving of 2% between 2000 and 2011 was assumed to be achieved in the above 5 sectors.

(3) Fuel consumption in 2011

As a result, fuel consumption of all fuels of these sectors was assumed to grow by the same ratio as that of the final energy consumption of each sector. Provincial fuel consumption by sector in 2011 was estimated as follows.

PSFCijk(2011) = PSFCijk(2000) x RRSECij x 0.98

Here,

PSFCijk(t): Provincial fuel consumption by sector and by fuel type

RRSECj: Ratio of final energy consumption of the sector of the region between 2011 and 2000 where the province locates

i : Province

j : Sector

k : Fuel type

0.98 : A ratio of energy saving between 2000 and 2011

The ratio of regional final energy consumption by sector between 2011 and 2000 is summarized in Table 3.3.2.1 and Figure 3.3.2.1.

Table 3.3.2.1 Ratio of Regional Final Energy Consumption by Sector between 2011 and 2000

Region	BMR	Central (1)	Northern	Northeastern	Southern	Eastern	Western (2)
Agriculture	1.23	0.62	1.06	1.14	1.14	0.69	1.02
Mining	1.52	1.48	1.29	1.45	1.45	1.02	1.23
Manufacturing	1.46	2.19	2.26	2.28	2.28	2.03	2.14
Construction	2.85	2.34	2.13	2.03	2.03	3.20	2.29
Residentai and Commercial	1.35	0.99	1.20	1.21	1.21	1.00	1.29

(1) Central region includes Chai Nat, Lop Buri, Saraburi, Sing Buri, Ayutthaya, Ang Thong.

(2) Western region includes Kanchanaburi, Prachuap Khiri Khan, Phetchaburi, Rachaburi, Samut Songkhram, Suphan Buri.

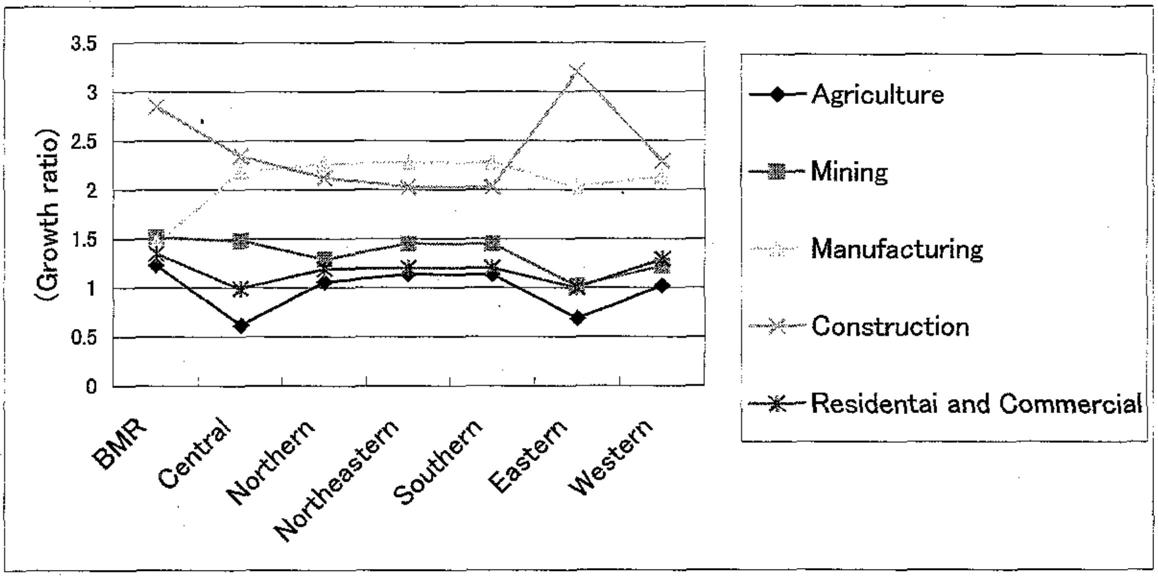

Figure 3.3.2.1 Regional Final Energy Consumption Growth between 2000 and 2011

4) Refinery

SOx emission from refineries was estimated independently as refineries supply petroleum fuels for both stationary and mobile sources. For emission from a refinery energy saving was also taken into consideration. Therefore, SOx emission from a refinery in 2011 was calculated by the following equation.

SOx emission in 2011 = TECG x SOx emission in 2000

Here,

TEGC: Ratio between total energy consumption by stationary and mobile sources in 2011 and that in 2000

The estimated TEGC value : 40,104 ktoe/27,602 ktoe =1.45

5) Effect of fuel conversion at cement plants on SOx emission

There are 3 cement plants which are to change their fuel. SOx emission from these plants after fuel conversion was calculated by the following equation (see Appendix 3.8).

SOx emission after fuel conversion = SOx emission before fuel conversion

x Ratio between amount of SOx emitted from fuels after fuel conversion and that before fuel conversion

6) Change of sulfur contents of gasoline and HSD

The sulfur contents of gasoline and HSD are expected to decrease from 0.0382 w% and 0.0348 w% into 0.0130 w% and 0.030 w% respectively due to the introduction of EURO 3.

7) Calculation method of emission of SOx and NOx

The method to calculate SOx and NOx emissions are the same as that of the Base Year.

3.3.2.2 Power Sector

Fuel consumption of EGAT power plants and IPPs in 2011 is forecasted as shown in Table 3.3.2.1. Compared to the year 2000, in the power sector, fuel conversion from Fuel Oil to imported coal is to be taken which will decrease SOx emission from the power sector.

Table 3.3.2.2 Forecast of Total Power Generation in 2011 (EGAT and IPP) by Fuel

Fuel	Total Power Generation in 2011 (GWh)	Share in 2011 (%)	Share in 2000 (%)
Natural gas	91,408	68.3	67.7
Fuel Oil	1,050	0.8	12.3
HSD	2	0.0	0.2
Lignite	16,255	12.1	19.9
Imported coal	25,094	18.8	
Total	133,809	100.0	100.1

Source: EGAT POWER DEVELOPMENT PLAN, PDP 2001, October 2001

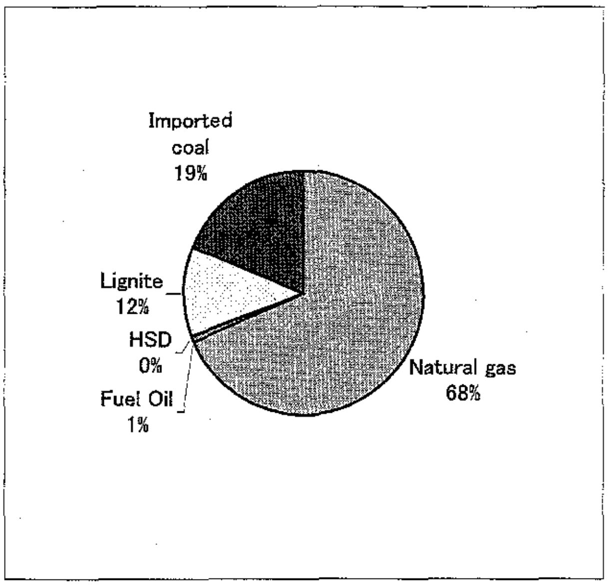

Figure 3.3.2.2 Share of Fuels in Power Generation (EGAT pp and IPP) in 2011

Figure 3.3.2.3 shows the flowchart for estimation of fuel consumption of the power sector in 2011.

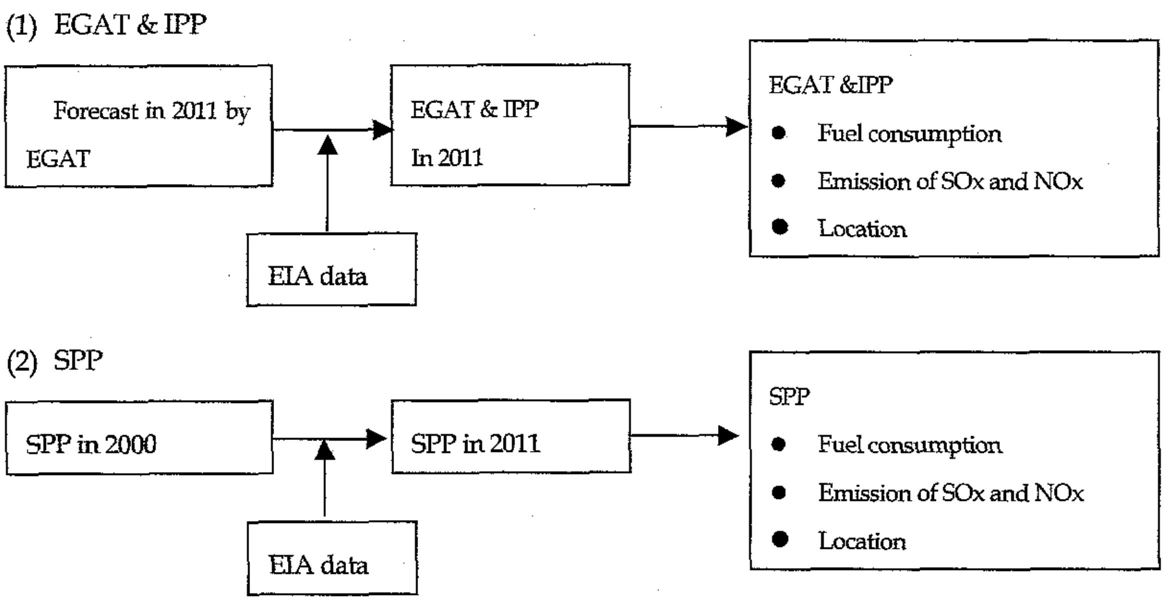

Figure 3.3.2.3 Flowchart for the Estimation of Fuel Consumption and SOx Emission of the Power Sector in 2011

1) EGAT power plant

Total fuel consumption by EGAT in 2011 is allocated to each power plant according to its power generation type and capacity.

2) IPP

Total fuel consumption by IPPs in 2011 is allocated to each power plant according to its power generation type and capacity.

3) SPP

Fuel consumption and SOx emission of each SPP with no expansion until the year 2011 were assumed to be the same as those in 2000. Fuel consumption of each SPP with an expansion plan is as in the EIA report.

3.3.2.3 The manufacturing sector

The conceptual diagram for the estimation of fuel consumption and SOx emission of the manufacturing sector in 2011 is shown in Figure 3.3.2.4.

1) Point source

Point sources of the manufacturing sector in 2011 consist of the following 3 types of sources.

(1) New point source starting operation between 2000 and 2011

(2) Existing point source in 2000 with expansion plan between 2000 and 2011

(3) Existing point source in 2000 without expansion plan between 2000 and 2011

For point sources of (1) and (2), their fuel consumption in 2011 was assumed to be that at their maximum operation as described in their EIA reports. For point sources of (3), their fuel consumption and SOx emission were estimated by the same method as shown in Section 3.3.2.1 3) (3).

2) Coal area source

Fuel consumption of the coal area source was calculated by the same method as shown in Section 3.3.2.1) (3).

3) Provincial area source

Fuel consumption of the provincial area source was calculated by the following equation.

Fuel consumption of area source = Provincial fuel consumption - all the fuel consumption of point sources in the province

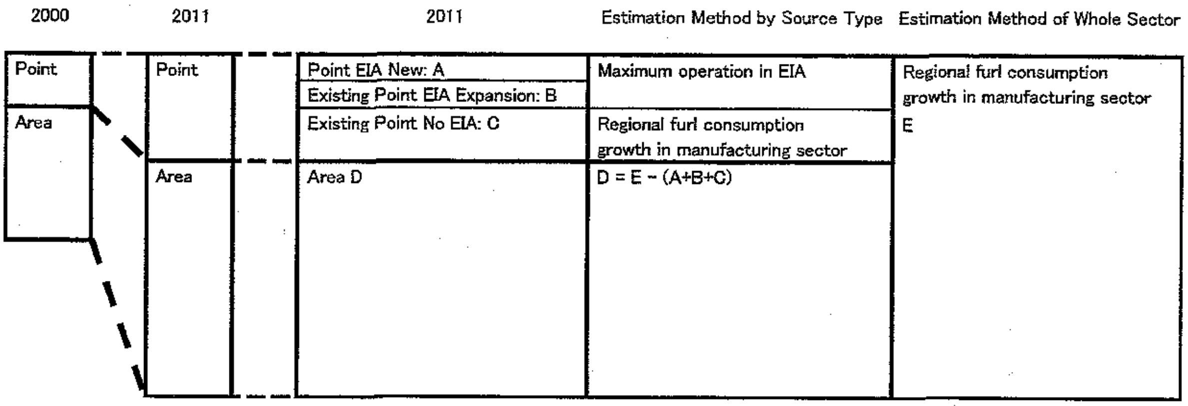

Figure 3.3.2.4 Conceptual Diagram of Fuel Consumption of The manufacturing sector in 2011

3.3.3 Estimated Fuel Consumption in the Whole of Thailand in 2011

3.3.3.1 Power sector

The fuel consumption of power plants in 2011 is summarized in Table 3.3.3.1. As shown in Section 3.3.2.2, fuel conversion from Fuel Oil to coal is planned.

Table 3.3.3.1 Fuel Consumption of Power Plants Connected to the National Grid (2011)

	Fuel Oil (1000 L)	HSD (1000 L)	NG (MMscf)	Lignite (ton)	Coal (ton)	Fuel wood (ton)	Paddy Husk (ton)	Baggase (ton)
EGAT	255,000	71,000	337,625	17,221,000				
IPP			340,545		9,473,000			
SPP	19,115	1,808	115,086	53,602	1,633,922	276,567	334,914	1,014,515
Total	274,115	72,808	793,256	17,274,602	11,106,922	276,567	334,914	1,014,515

3.3.3.2 Agriculture sector

Fuel consumption of the agriculture sector in 2011 is summarized in Table 3.3.3.2.

Table 3.3.3.2 Fuel Consumption of the Agriculture Sector in 2011

	ULG 91 (KL)	ULG 95 (KL)	Kerosene (KL)	HSD (KL)	Fuel Oil (KL)	LPG (KL)	Fuel Wood (Kton)	Paddy Husk (Kton)
BMR	7,455	345	92	268,210	387	303	1,832	288
Central Region	6,663	308	82	239,717	346	271	1,638	257
Northern Region	13,123	607	162	472,132	681	533	3,226	507
Northeastern Region	15,777	730	195	567,617	818	641	3,878	609
Southern Region	34,550	1,599	426	1,243,024	1,792	1,404	8,493	1,334
Eastern Region	3,849	178	47	138,478	200	156	946	149
Total	81,416	3,768	1,005	2,929,180	4,223	3,307	20,013	3,143

3.3.3.3 Mining sector

Fuel consumption of the mining sector in 2011 is summarized in Table 3.3.3.3.

Table 3.3.3.3 Fuel Consumption of Mining Sector in 2011

	HSD (KL)	LSD (KL)	Fuel Oil (KL)
BMR	215	28	26
Central Region	1,943	255	232
Northern Region	229	30	27
Northeastern Region	3,876	510	463
Southern Region	1,194	157	143
Eastern Region	5,261	692	628
Total	12,717	1,673	1,518

3.3.3.4 Manufacturing sector

Fuel consumption of the the manufacturing sector in 2011 is shown in Table 3.3.3.4.

Table 3.3.3.4 Fuel Consumption of the Manufacturing Sector in 2011

	ULG 91 (KL)	ULG 95 (KL)	Kerosene (KL)	HSD (KL)	LSD (KL)	Fuel Oil (KL)	LPG (KL)
BMR	1,616	14,597	44,979	415,990	9,496	3,002,060	492,773
Central Region	410	845	3,371	312,326	5,875	683,111	116,706
Northern Region	5,760	6,710	67	195,037	239	113,850	44,597
Northeastern Region	9,227	2,318	47	166,356	475	246,190	74,242
Southern Region	2,638	2,933	122	117,716	0	271,101	17,657
Eastern Region	5,878	10,407	2,152	256,982	12,832	990,998	273,968
Total	25,529	37,811	50,738	1,464,406	28,916	5,307,308	1,019,943

	Coal (ton)	Lignite (ton)	Natural gas (MMscf)	Fuel wood (kton)	Paddy husk (kton)	Bagasse (kton)
BMR	249,481	207,281	30,177	1,553	1,888	13,021
Central Region	4,953,158	4,883,566	3,385	368	447	3,084
Northern Region	216,859	1,158,814		141	171	1,178
Northeastern Region	673,342	181,518		234	285	1,962
Southern Region	101,207	377,433		56	68	467
Eastern Region	557,729	395,502	70,170	863	1,050	7,239
Total	6,751,775	7,204,114	103,731	3,214	3,909	26,950

3.3.3.5 Construction sector

The fuel consumption of the construction sector in 2011 is shown in Tables 3.3.3.5.

Table 3.3.3.5 Fuel Consumption of The Construction sector in 2011

	ULG 91 (KL)	HSD (KL)	Fuel Oil (KL)
BMR	11	179,213	31,240
Central Region	2	30,906	5,387
Northern Region	2	38,796	6,763
Northeastern Region	3	49,152	8,568
Southern Region	2	29,728	5,182
Eastern Region	2	35,433	6,176
Total	23	363,227	63,316

3.3.3.6 Residential and Commercial sector

Fuel consumption of the residential and commercial sector in 2011 is shown in Tables 3.3.3.6

. Table 3.3.3.6 Fuel Consumption oft the Residential and Commercial Sector in 2011

	Kerosene (KL)	LSD (KL)	Fuel Oil (KL)	LPG (KL)	Fuel wood (kton)	Charcoal (Kton)	Paddy husk (Kton)
BMR	1,286	100	1,922	668,728	212	115	4
Central	1,961	60	1,150	296,442	955	470	18
Northern Region	3,732	114	2,188	564,155	1,817	895	34
Northeastern Region	6,654	203	3,902	1,006,065	3,241	1,596	61
Southern Region	2,513	77	1,474	379,965	1,224	603	23
Eastern Region	1,078	33	632	162,958	525	258	10
Total	17,224	588	11,267	3,078,313	7,974	3,936	149

3.3.4 Estimated Fuel Consumption in the BMR

3.3.4.1 Power Sector

Provincial fuel consumption by the power sector in the BMR in 2011 is shown in Table3.3.4.1. Fuel Oil is not used in the power sector in 2011 due to the conversion of Fuel Oil into Natural gas at South Bangkok and North Bangkok Power Stations.

Table 3.3.4.1 Fuel Consumption by Power Plants in the BMR in 2011

	Fuel Oil (KL)	HSD (KL)	Natural Gas MMscf
Bangkok			
Nonthaburi		5,627	79,409
Pathum Thani			
Samut Prakan		21,468	43,631
Samut Sakhon			
Nakhon Pathom			
Total		27,095	123,041

3.3.4.2 Agriculture Sector

Provincial fuel consumption by the agriculture sector in the BMR in 2011 is shown in Table 3.3.4.2.

Table 3.3.4.2 Fuel Consumption by the Agriculture Sector in BMR in 2011

	ULG91 (KL)	ULG95 (KL)	Kerosene (KL)	HSD (KL)	Fuel Oil (KL)	LPG (KL)	Fuel Wood (Kton)	Paddy Husk (Kton)
Bangkok	1,532	71	19	55,130	79	62	377	59
Nonthaburi	317	15	4	11,413	16	13	78	12
Pathum Thani	482	22	6	17,345	25	20	119	19
Samut Prakan	2,176	101	27	78,306	113	88	535	84
Samut Sakhon	1,825	84	23	65,649	95	74	449	70
Nakhon Pathom	1,122	52	14	40,368	58	46	276	43
Total	7,455	345	92	268,210	387	303	1,832	288

3.3.4.3 Mining Sector

Provincial fuel consumption by the mining sector in the BMR in 2011 is shown in Table 3.3.4.3.

Table 3.3.4.3 Fuel Consumption by the Mining Sector in the BMR in 2011

	HSD (KL)	LSD (KL)	Fuel Oil (KL)
Bangkok			
Nonthaburi			
Pathum Thani	11	1	1
Samut Prakan			
Samut Sakhon	191	25	23
Nakhon Pathom	13	2	2
Total	215	28	26

3.3.4.4 Manufacturing sector

Provincial fuel consumption by the manufacturing sector in the BMR in 2011 is shown in Table 3.3.4.4.

Table 3.3.4.4 Fuel Consumption by the Manufacturing sector in the BMR in 2011

	ULG91 (KL)	ULG95 (KL)	Kerosene (KL)	HSD (KL)	LSD (KL)	Fuel Oil (KL)	LPG (KL)
Bangkok	1,065	9,320	33,445	191,827	6,182	1,035,203	301,120
Nonthaburi	37	322	310	10,781	104	54,635	14,523
Pathum Thani	125	2,170	341	51,333	638	334,805	59,395
Samut Prakan	188	2,637	9,588	70,620	2,571	762,530	64,507
Samut Sakhon	78	1	1,031	62,724		653,206	36,072
Nakhon Pathom	124	147	265	28,706		161,681	17,158
Total	1,616	14,597	44,979	415,990	9,496	3,002,060	492,773

	Coal (ton)	Lignite (ton)	Natural Gas (MMscf)	Fuel Wood (Kton)	Paddy Husk (Kton)	Bagasse (Kton)
Bangkok	36,023	9,197	545	949	1,154	7,957
Nonthaburi	0	0	0	46	56	384
Pathum Thani	7,236	1,847	1,005	187	228	1,569
Samut Prakan	12,210	70,151	28,627	203	247	1,704
Samut Sakhon	164,618	118,584	0	114	138	953
Nakhon Pathom	29,394	7,502	0	54	66	453
Total	249,481	207,281	30,177	1,553	1,888	13,021

3.3.4.5 The construction sector

Provincial fuel consumption by the construction sector in the BMR in 2011 is shown in Table 3.3.4.5.

Table 3.3.4.5 Fuel Consumption by the Construction Sector in the BMR in 2011

	ULG91 (KL)	HSD (KL)	Fuel Oil (KL)
Bangkok	9.1	145,962	25,443
Nonthaburi	0.7	10,969	1,912
Pathum Thani	0.3	5,349	932
Samut Prakan	0.5	8,472	1,477
Samut Sakhon	0.3	4,305	750
Nakhon Pathom	0.3	4,157	725
Total	11.2	179,213	31,240

3.3.4.6 Residential and Commercial Sector

Provincial fuel consumption by the residential and commercial sector in the BMR in 2011 is shown in Table 3.3.4.6.

Table 3.3.4.6 Fuel Consumption by the Residential and Commercial Sector in the BMR in 2011

	Kerosene (KL)	LSD (KL)	Fuel Oil (KL)	LPG (KL)	Fuel Wood (Kton)	Charcoal (Kton)	Paddy Husk (Kton)
Bangkok	600	61	1,162	419,532	5	9	
Nonthaburi	91	9	176	63,487	1	1	
Pathum Thani	69	7	134	48,354	1	1	
Samut Prakan	105	11	204	73,549	1	2	
Samut Sakhon	150	5	88	22,613	73	36	1.4
Nakhon Pathom	272	8	160	41,192	133	65	2.5
Total	1,286	100	1,922	668,728	212	115	3.8

3.3.5 SOx Emission in the Whole of Thailand

3.3.5.1 SOx Emission by Sector

Sectoral SOx emission in 2011 is given in Table 3.3.5.1 and Figure 3.3.5.1. The annual total SOx emission in Thailand in 2011 is 542 thousand tons. Among them, the manufacturing sector accounts for 324 thousand tons (59.8%), followed by the power sector (161 thousand tons, 29.7%) and refinery (4 thousand tons, 9.0%). The total of these three sectors' share is 98.5%.

Table 3.3.5.1 Annual SOx Emission by Sector in 2011

Sector	SOx Emission (ton/Y)	Share (%)
Power	161,024	29.7
Agriculture	2,493	0.5
Mining	68	0.0
Manufacturing	324,464	59.8
Construction	2,224	0.4
Residential and Commercial	3,362	0.6
Refinery	48,981	9.0
Total	542,616	100.0

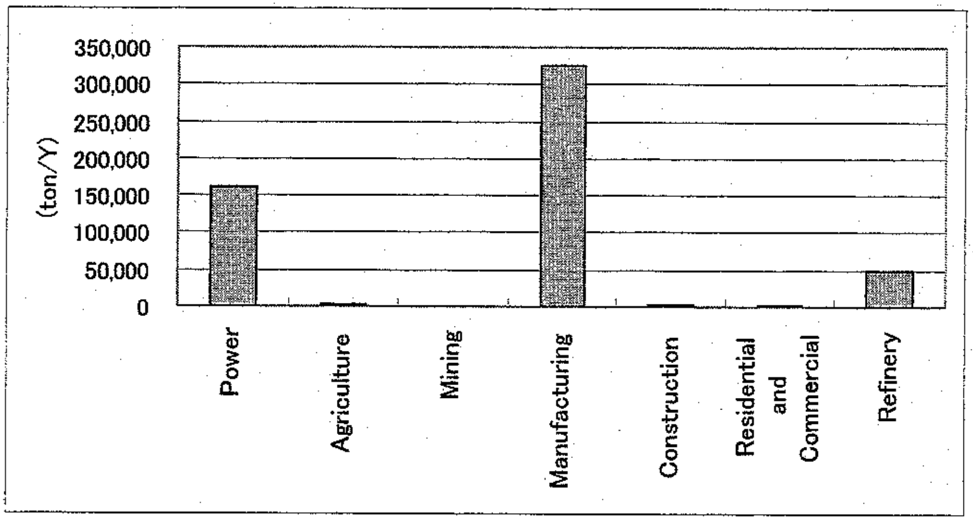

Figure 3.3.5.1 Total SOx Emission by Sector in 2011

3.3.5.2 SOx Emission of Point and Area Sources

The annual SOx emission by point sources in 2011 is shown in Table 3.3.5.2 and Figure 3.3.5.2. The share of the manufacturing sector, other than cement plants, is the highest at 36.0% (135 thousand tons followed by Independent Power Plants (IPP) (23.4%, 89 thousand tons).

Table 3.3.5.2 Annual SOx Emission by Point Sources in 2000

		(ton/Y)	% share
Power Plant	EGAT	48,095	12.6
	IPP	89,130	23.4
	SPP	23,800	6.3
	Total	161,024	42.3
Refinery		48,981	12.9
Cement plant		33,199	8.7
Other		137,032	36.0
Total		380,236	100.0

Annual SOx emission from point and area sources in 2011 is summarized in Table 3.3.5.3. About 70% of the total SOx emission is covered by point sources.

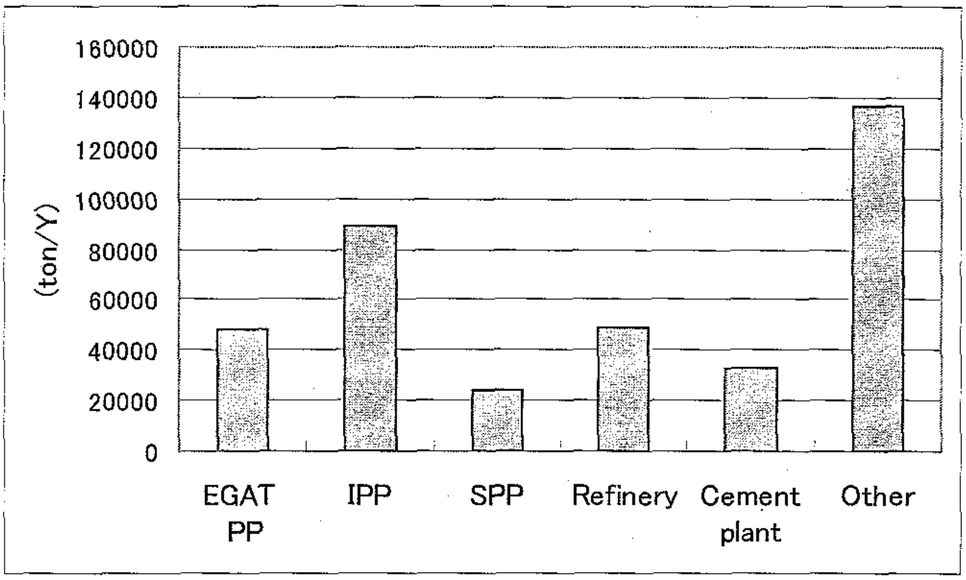

Figure 3.3.5.2 SOx Emission by Point Sources in 2011

Table 3.3.5.3 Annual SOx Emission from Point and Area Sources in 2011

	SOx Emission (ton/Y)	Share (%)
Point	380,236	70.1
Area	162,380	29.9
Total	542,616	100.0

3.3.5.3 SOx Emission by Province

Annual SOx emission by province is summarized in Table 3.3.5.4 and Figure 3.3.5.3. Provinces emitting more than 10,000 tons in 2011 are shown in Table 3.3.5.5 and Figure 3.3.5.4. Rayong emits the largest amount of SOx at 94,700 tons, followed by Prachuap Khiri Khan (62,300 tons). These 13 provinces account for 86% of the total SOx emission in Thailand in 2011.

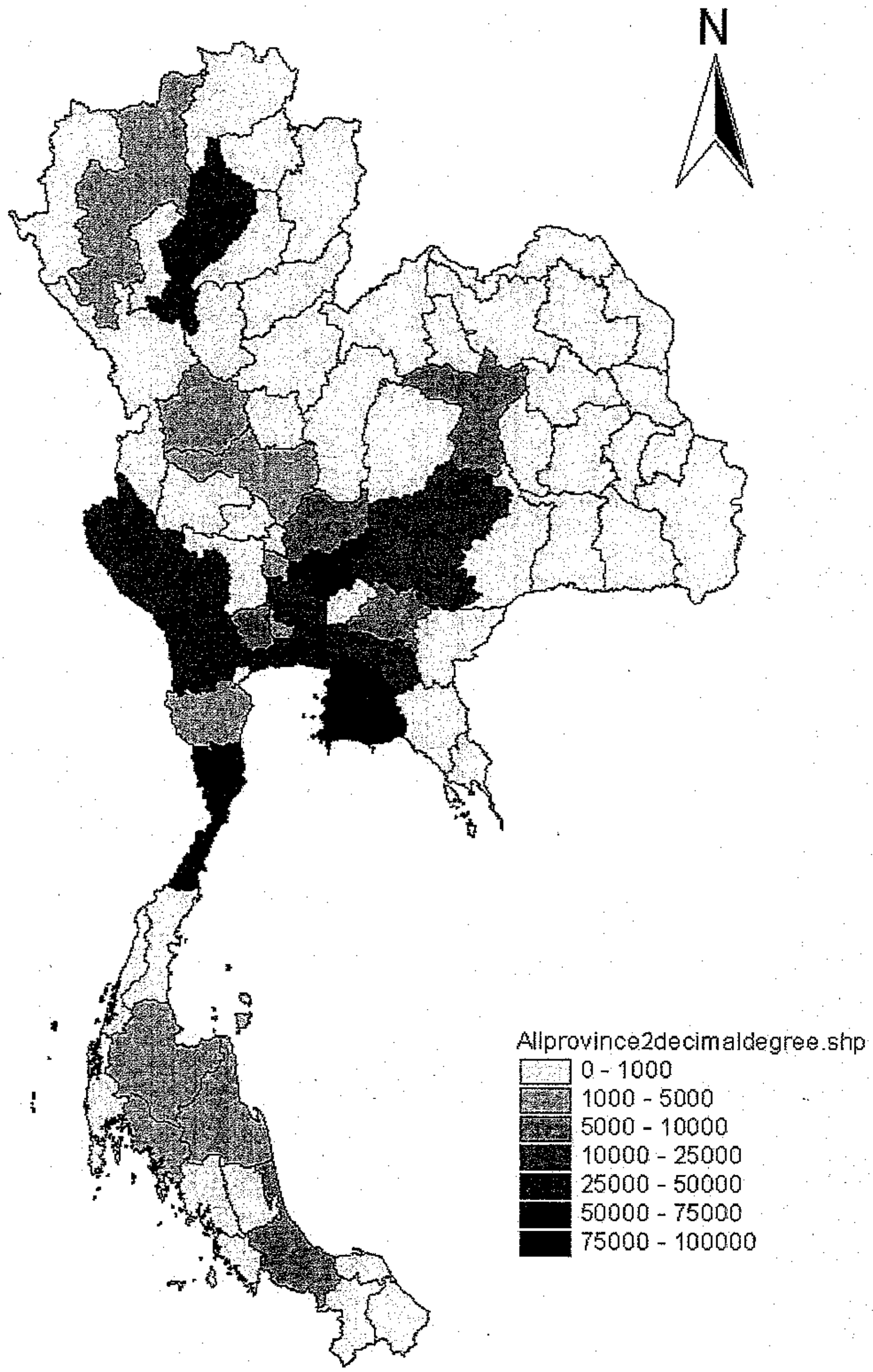

Figure 3.3.5.3 Distribution of Provincial SOx Emission in Thailand in 2011

Table 3.3.5.4 (1) SOx Emission by Province in 2011

(ton/Y)

No.	Province	Power	Refinery	Manufacturing			Other	Total
				Cement	Other	Total		
	BMR	110	822		104,875	104,875	1,576	107,384
1	Bangkok		822		23,213	23,213	1,057	25,092
2	Nonthaburi	19			4,253	4,253	94	4,367
3	Pathum Thani				20,220	20,220	61	20,281
4	Samut Prakan	91			30,421	30,421	139	30,651
5	Samut Sakhon				19,294	19,294	112	19,406
6	Nakhon Pathom				7,474	7,474	113	7,588
	Central	58,664		24,178	90,032	114,210	787	173,661
7	Kanchanaburi				11,696	11,696	104	11,800
8	Chai Nat	1			63	63	50	115
9	Prachuap Khiri Khan	56,702			5,553	5,553	68	62,323
10	Phetchaburi			600	1,745	2,344	58	2,402
11	Ratchaburi	131		288	10,459	10,747	104	10,983
12	Lop Buri	4			9,441	9,441	84	9,528
13	Samut Songkhram				74	74	21	95
14	Saraburi	1,615		23,291	37,036	60,327	57	61,999
15	Sing Buri				481	481	18	499
16	Suphan Buri	6			222	222	125	353
17	Ayutthaya	206			11,455	11,455	73	11,734
18	Ang Thong				1,807	1,807	23	1,830
	Northern Region	39,095	4	6,695	9,065	15,760	1,369	56,228
	upper part	39,080	4	5,253	6,160	11,413	682	51,180
19	Chiang Rai				677	677	115	793
20	Chiang Mai	333	4		1,615	1,615	175	2,126
21	Nan				332	332	72	404
22	Phayao				248	248	48	295
23	Phrae				323	323	55	378
24	Mae Hong Son				1	1	28	29
25	Lampang	38,747		5,253	2,140	7,392	88	46,227
26	Lamphun				825	825	101	926
	lower part	15		1,442	2,905	4,347	687	5,049
27	Kamphaeng Phet	6			1,210	1,210	111	1,327
28	Tak				657	657	68	724
29	Nakhon Sawan	7		1,442	529	1,971	89	2,067
30	Phichit				32	32	55	88
31	Phitsanulok				92	92	116	207
32	Phetchabun				123	123	82	205
33	Sukhothai				115	115	70	185
34	Uttaradit	2			68	68	44	114
35	Uthai Thani				78	78	53	132
	Northeastern Region	865			20,139	20,139	2,104	23,108
	upper part	849			7,967	7,967	1,053	9,869
36	Kalasin				469	469	84	553
37	Khon Kaen	847			6,244	6,244	199	7,290
38	Nakhon Phanom				39	39	68	107
39	Maha Sarakham				97	97	107	204
40	Mukdahan				19	19	54	73
41	Roi Et	2			26	26	101	128
42	Loei				97	97	64	160
43	Sakon Nakhon				82	82	96	178
44	Nong Khai				365	365	71	436
45	Nong Bua Lam Phu				56	56	74	129
46	Udon Thani				474	474	136	610
	lower part	16			12,172	12,172	1,051	13,239
47	Chaiyaphum	4			535	535	124	663
48	Nakhon Ratchasima	12			11,089	11,089	233	11,334
49	Buri Ram				84	84	130	214
50	Yasothon				38	38	80	118
51	Si Sa Ket				44	44	137	181
52	Surin				75	75	111	186
53	Amnat Charoen				15	15	61	76
54	Ubon Ratchathani				292	292	176	468

Table 3.3.5.4 (2) SOx Emission by Province in 2011

(ton/Y)

No.	Province	Power	Refinery	Manufacturing			Other	Total
				Cement	Other	Total		
	Southern Region	982		2,326	10,127	12,452	1,737	15,172
	upper part	982		2,326	3,451	5,777	858	7,616
55	Krabi	949			73	73	99	1,121
56	Chumphon				264	264	92	356
57	Nakhon Si Thammarat	25		2,326	978	3,304	273	3,601
58	Phangnga				132	132	80	211
59	Phuket				381	381	51	433
60	Ranong				67	67	50	117
61	Surat Thani	8			1,555	1,555	214	1,777
	lower part				6,676	6,676	879	7,555
62	Trang				23	23	148	172
63	Narathiwat				98	98	107	205
64	Pattani				295	295	127	422
65	Phathalung				4	4	68	72
66	Yala				55	55	77	131
67	Songkhla				6,172	6,172	281	6,454
68	Satun				29	29	71	99
	Eastern Region	61,307	48,155		57,027	57,027	574	167,063
69	Chanthaburi				348	348	52	400
70	Chachoengsao	7,391			4,364	4,364	84	11,840
71	Chon Buri	72	22,810		27,270	27,270	185	50,338
72	Trat				7	7	28	36
73	Nakhon Nayok				49	49	25	74
74	Prachin Buri	2,508			6,807	6,807	51	9,366
75	Rayong	51,336	25,344		18,012	18,012	97	94,789
76	Sa Kaeo				170	170	51	220
	Total	161,024	48,981	33,199	291,265	384,037	8,147	542,616

Table 3.3.5.5 Provinces Emitting More Than 10,000 tons of SOx in 2011

	Province	SOx (ton/Y)
1	Rayong	94,789
2	Prachuap Khiri Khan	62,323
3	Saraburi	61,999
4	Chon Buri	50,338
5	Lampang	46,227
6	Samut Prakan	30,651
7	Bangkok	25,092
8	Pathum Thani	20,281
9	Samut Sakhon	19,406
10	Chachoengsao	11,840
11	Kanchanaburi	11,800
12	Ayutthaya	11,734
13	Nakhon Ratchasima	11,334
14	Ratchaburi	10,983
	Total	468,798

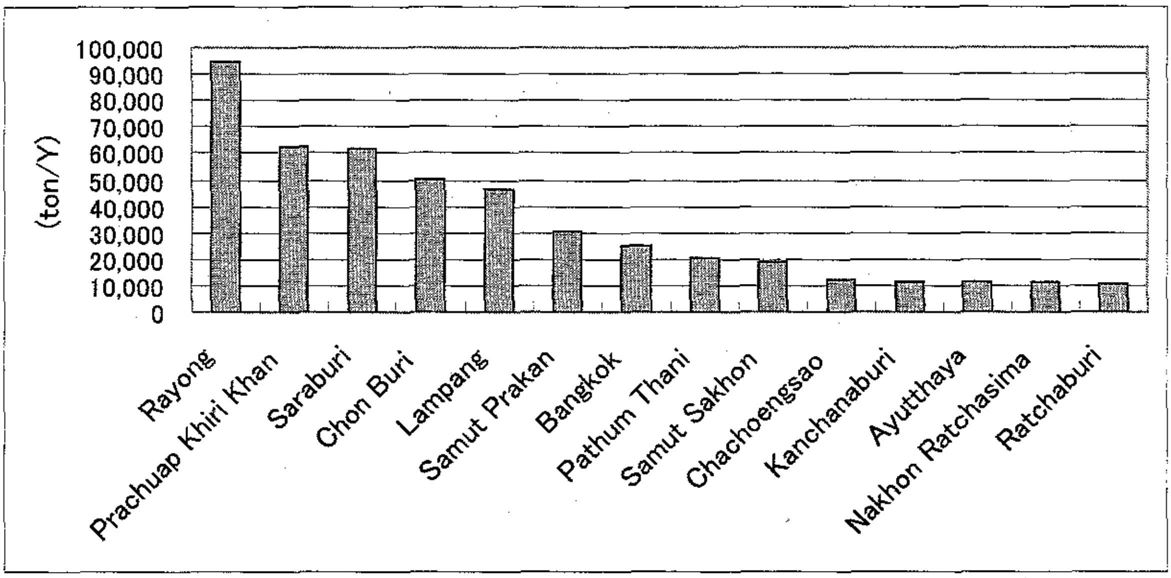

Figure 3.3.5.4 Provinces Emitting More than 10,000 tons of SOx in 2011

3.3.5.4 SOx Emission by Region

SOx emission by region is shown in Table 3.3.5.6 and Figure 3.3.5.5. The central region emits 171.6 thousand tons of SOx, (31.8%)of the total SOx emission, followed by the Eastern Region (169.8 tons, 31,4%).

Table 3.3.5.6 Regional SOx Emission in 2011

Region	SOx Emission (ton/Y)	Share (%)
BMR	107,384	19.8
Central	173,661	32.0
Northern	56,228	10.4
Northeastern	23,108	4.3
Southern	15,172	2.8
Eastern	167,063	30.8
Total	542,616	100.0

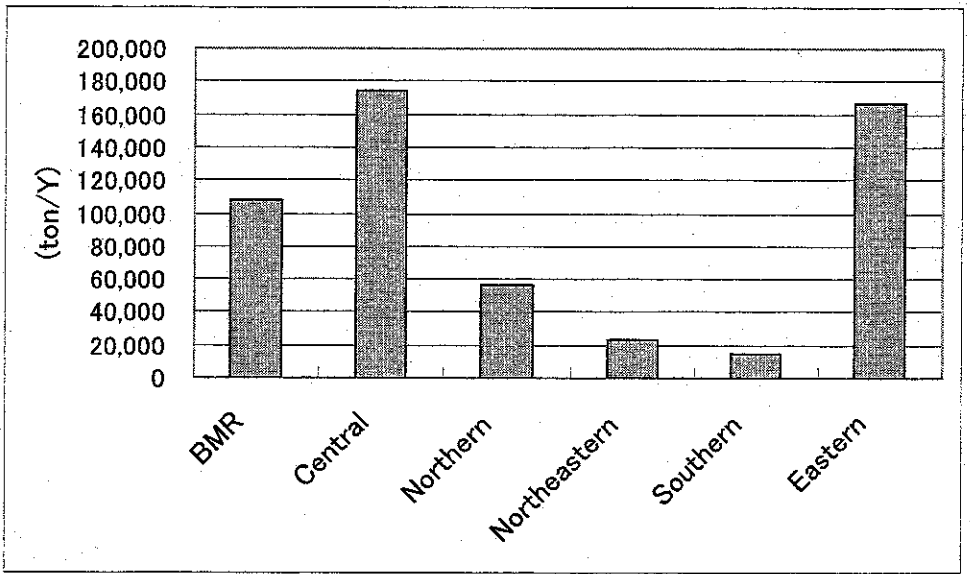

Figure 3.3.5.5 SOx Emission by Region in 2011

3.3.6 Comparison of SOx Emission between 2011 and 2000 in the Whole of Thailand

Comparison of SOx emission in the whole of Thailand between 2000 and 2011 is summarized in Table 3.3.6.1 and Figure 3.3.6.1. The total SOx emission from stationary sources increases from 326 thousand tons to 542 thousand tones. During 11 years, it increases by 66 %.

Concerning sectoral share changes, the share of the power sector decreases to 3.8 % and the share of the manufacturing sector increases to 5.5 %.

Table 3.3.6.1 Comparison of SOx Emission between 2011 and 2000

Sector	2000		2011	
	SOx Emission (ton/Y)	Share (%)	SOx Emission (ton/Y)	Share (%)
Power	109,415	33.5	161,024	29.7
Agriculture	2,283	0.7	2,493	0.5
Mining	57	0.0	68	0.0
Manufacturing	177,085	54.3	324,464	59.8
Construction	896	0.3	2,224	0.4
Residentail and Commercial	2,827	0.9	3,362	0.6
Refinery	33,712	10.3	48,981	9.0
Total	326,275	100.0	542,616	100.0

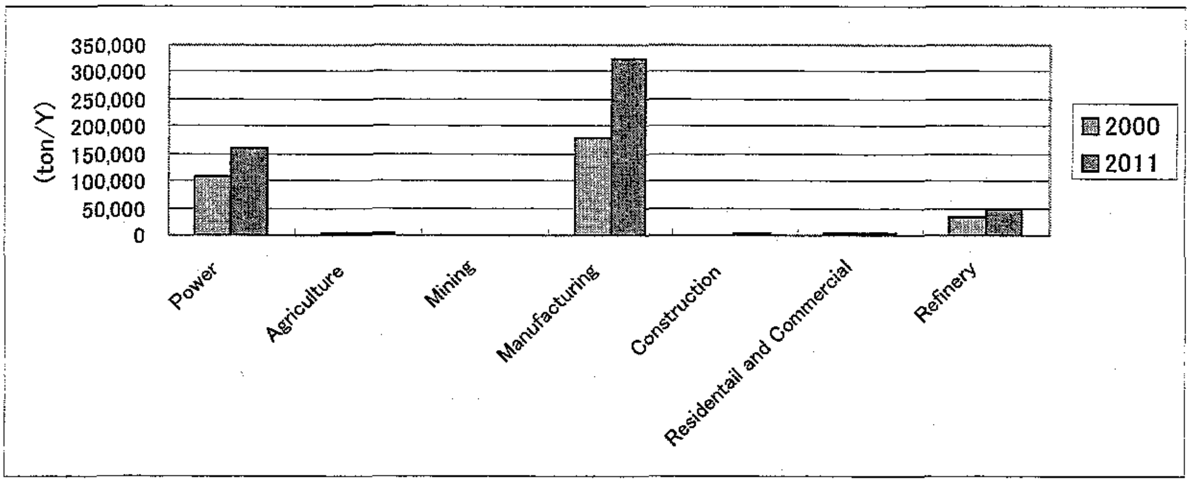

Figure 3.3.6.1 Comparison of SOx Emission by Sector between 2011 and 2000

Table 3.3.6.2 and Figure 3.3.6.2 show change of share of EGAT power plants, IPPs and SPPs between 2000 and 2011. Between these 11 years, the share of EGAT power plants decreases from 31.3 % to 8.9 %. While, the share of IPP increases from 0.4 % to 16.4 % due to the installation of new coal power plants.

Table3.3.6.2 Change of Share of Power Plants to Total SOx Emission

Source	2000		2011	
	SOx emission (ton/Y)	Share (%)	SOx emission (ton/Y)	Share (%)
EGAT PP	102,121	31.3	48,095	8.9
IPP	1,269	0.4	89,130	16.4
SPP	6,026	1.8	23,800	4.4
Other source	216,859	66.5	381,592	70.3
Total	326,275	100.0	542,616	100.0

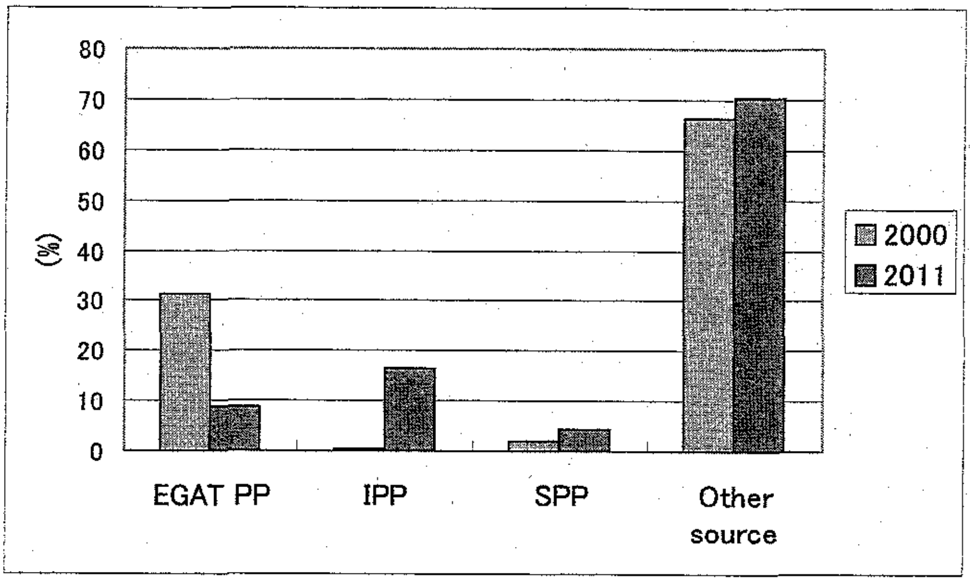

Figure 3.3.6.2 Change of Share of Power Plants by Type between 2000 and 2011

Table 3.3.6.3 and Figure 3.3.6.3 gives the changes of regional SOx emission between 2000 and 2011. Emission of the Central and Eastern Regions increase largely in these 11 years.

Table 3.3.6.3 Change of Regional SOx Emission between 2000 and 2011

Region	2000		2011	
	SOx Emission (ton/Y)	Share (%)	SOx Emission (ton/Y)	Share (%)
BMR	100,728	30.9	107,384	19.8
Central	63,079	19.3	173,661	32.0
Northern	45,399	13.9	56,228	10.4
Northeastern	11,486	3.5	23,108	4.3
Southern	11,201	3.4	15,172	2.8
Eastern	94,383	28.9	167,063	30.8
Total	326,275	100.0	542,616	100.0

Figure 3.3.6.3 Change of Regional SOx Emission between 2000 and 2011

3.3.7 SOx and NOx Emission in the BMR in 2011

3.3.7.1 SOx Emission in 2011

Table 3.3.7.1 and Figure 3.3.7.1 show the annual SOx emission in the BMR in 2011. The total annual emission of SOx in 2011 is 107 thousand tons, of which Samut Prakan accounts for 28.5 % followed by Bangkok (23.4 %) and Pathum Thani (18.9 %) and Samut Sakhon (18.1%).

Table 3.3.7.1 Annual SOx Emission in the BMR in 2011

(Uint: ton/Y)

	Point				Area						
Province	Power plants	Refinery	Other	Sub-total	Agriculture	Mining	Construction	Resi. & Comm.	Sub-otal	Total	% share
Bangkok		822	23,213	24,035	47		894	116	1,057	25,092	23.4
Nonthaburi	19	0	4,253	4,273	10		67	18	94	4,367	4.1
Pathum Thani		0	20,220	20,220	15	0.1	33	13	61	20,281	18.9
Samut Prakan	91	0	30,421	30,512	67		52	20	139	30,651	28.5
Samut Sakhon		0	19,294	19,294	56	1.0	26	29	112	19,406	18.1
Nakhon Pathom		0	7,474	7,474	34	0.1	25	53	113	7,588	7.1
Total	110	822	104,875	105,808	228	1.2	1,098	249	1,576	107,384	100.0

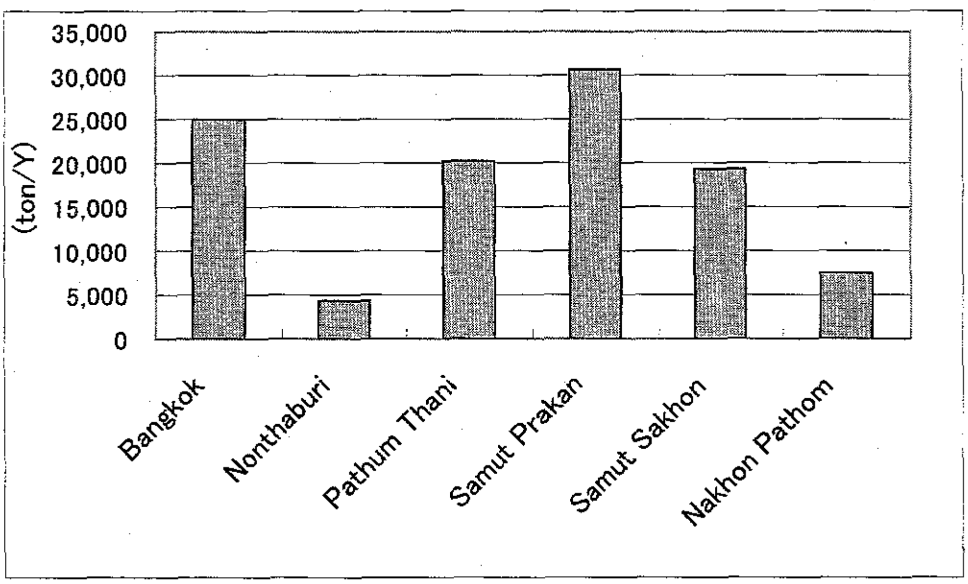

Figure 3.3.7.1 Provincial SOx Emission in the BMR in 2011

3.3.7.2 NOx Emission in 2011

Table 3.3.7.2 and Figure 3.3.7.2 show the annual NOx emission in the BMR in 2011. The total annual total emission of NOx in 2011 is 70.8 thousand tons, of which Samut Prakan accounts for 2.1 % followed by Bangkok (24,1%) and Pathum Thani (17.9 %).

Table 3.3.7.2 Annual NOx Emission in the BMR in 2011

(Uint: ton/Y)

Province	Point				Area					Total	% share
	Power plants	Refinery	Other	Sub-total	Agriculture	Mining	Construction	Resi. & Comm.	Sub-otal		
Bangkok		1,143	6,457	7,601	2,681	0.0	5,687	1,105	9,473	17,074	24.1
Nonthaburi	915		1,462	2,376	1,962	0.0	161	117	2,240	4,616	6.5
Pathum Thani			11,560	11,560	555	0.0	427	165	1,148	12,707	17.9
Samut Prakan	9,530		9,879	19,409	845	7.0	208	128	1,188	20,596	29.1
Samut Sakhon			5,742	5,742	3,807	0.0	330	194	4,332	10,075	14.2
Nakhon Pathom			2,355	2,355	3,192	0.0	168	65	3,425	5,779	8.2
Total	10,445	1,143	37,454	49,042	13,042	7	6,982	1,774	21,805	70,847	100.0

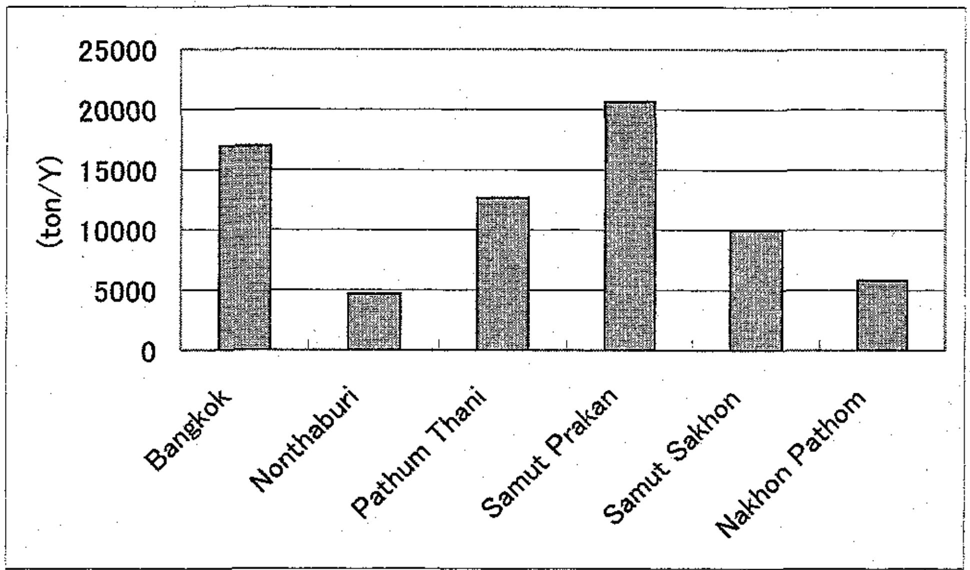

Figure 3.3.7.2 Provincial NOx Emission in the BMR in 2011

3.3.7.3 Comparison of SOx and NOx Emission between 2011 and 2000

Comparison of SOx emission between 2000 and 2011 is summarized in Table 3.3.7.3. The total SOx emission from stationary sources in 2011 is almost at the same level in 2000 due to the fuel conversion of North Bangkok and South Bangkok Power Stations from Fuel Oil into natural gas.

The total SOx emission from power plants decreases by 27.4 thousand tons. The changes of provincial SOx emission are shown in Figure 3.3.7.3.

Table 3.3.7.3 Comparison of SOx Emission between 2011 and 2000

(ton/Y)

	2000						2011					
	Point			Area	Total	Share (%)	Point			Area	Total	Share (%)
	Power	Other	Total				Power	Other	Total			
Bangkok	1	16,468	16,469	445	16,914	16.8		24,035	24,035	1,057	25,092	23.4
Nonthaburi	2,756	2,914	5,669	46	5,715	5.7	19	4,253	4,273	94	4,367	4.1
Pathum Thani		13,852	13,852	35	13,887	13.8		20,220	20,220	61	20,281	18.9
Samut Prakan	24,777	20,843	45,620	93	45,714	45.4	91	30,421	30,512	139	30,651	28.5
Samut Sakhon		13,217	13,217	82	13,298	13.2		19,294	19,294	112	19,406	18.1
Nakhon Pathom		5,120	5,120	79	5,200	5.2		7,474	7,474	113	7,588	7.1
Total	27,534	72,414	99,948	780	100,728	100.0	110	105,698	105,808	1,576	107,384	100.0

Figure 3.3.7.3 Change of Provincial SOx Emission in the BMR between 2000 and 2011

Comparison of NOx emission between 2000 and 2011 is summarized in Table 3.3.7.4. Increase of the total NOx emission from stationary sources from 2000 to 2011 in the BMR is only 4 thousand tons. This is due to the fuel conversion of North Bangkok and South Bangkok Power Stations from Fuel Oil into natural gas together with the introduction of NOx abatement measures. NOx emission from power plants decreases by 8.5 thousand tons. Figure 3.3.7.4 shows the change of provincial NOx emission in the BMR between 2000 and 2011.

Table 3.3.7.4 Comparison of NOx Emission in the BMR between 2011 and 2000

(ton/Y)

	2000						2011					
	Point			Area	Total	Share	Point			Area	Total	Share
	Power	Other	Total			(%)	Power	Other	Total			(%)
Bangkok	93	6,980	7,073	4,980	12,053	18.0		6,457	7,601	9,473	17,074	24.1
Nonthaburi	301	1,250	1,551	1,728	3,279	4.9	915	1,462	2,376	2,240	4,616	6.5
Pathum Thani		9,459	9,459	721	10,180	15.2		11,560	11,560	1,148	12,707	17.9
Samut Prakan	18,579	8,853	27,432	856	28,289	42.2	9,530	9,879	19,409	1,188	20,596	29.1
Samut Sakhon		5,053	5,053	3,342	8,394	12.5		5,742	5,742	4,332	10,075	14.2
Nakhon Pathom		2,104	2,104	2,689	4,793	7.2		2,355	2,355	3,425	5,779	8.2
Total	18,973	33,699	52,672	14,317	66,988	100.0	10,445	37,454	49,042	21,805	70,847	100.0

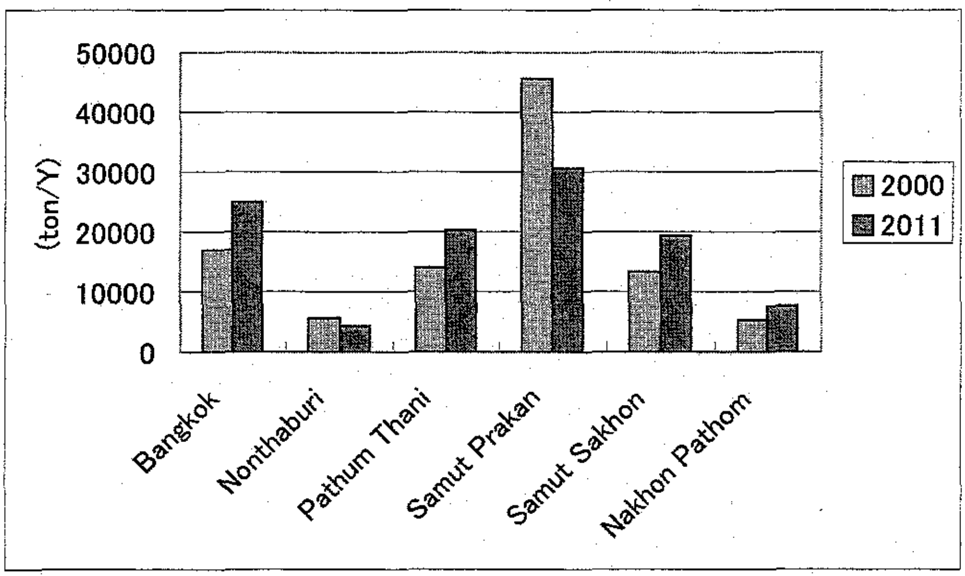

Figure 3.3.7.4 Change of Provincial NOx Emission in the BMR between 2000 and 2011

Charpter 4

Mobile Source Inventory

4. Mobile Source Inventory

4.1 Outline

4.1.1 Objectives

The objectives of the mobile source inventory development are as follows;

- **To estimate fuel consumption and SOx emission of mobile source (vehicles, railway, ships, and aircraft) in the year 2000 (base year) and the year 2011 (Target year) in the whole Thailand**
- **To estimate NOx and SOx emission of mobile source in the year 2000 and the year 2011 in the BMR (Bangkok Metropolitan Region)**
- **To develop the mobile source inventory using the information mentioned above**

The flow of mobile source inventory development is shown in Figure 4.1.1.1.
Firstly, the fuel consumption, SOx and NOx emission in the year 2000 is estimated using traffic data of mobile source (vehicles, railway, ships, aircraft) and using the fuel consumption rate, NOx emission factor of the mobile source and the sulfur contents in fuel.

Secondly, the traffic data of the mobile source in the year 2011 is estimated using traffic data of the year 2000 and the growth rate or forecasted traffic volume based on the future plan of each mobile sector. The fuel consumption rate, NOx emission factor of the mobile source and the sulfur contents in fuel in the year 2011 are estimated based on the future plans and regulations of each mobile sector.

Finally, the fuel consumption, SOx and NOx emission in the year 2011 are estimated using estimated traffic data of the mobile source and using the estimated fuel consumption rate, NOx emission factor of the mobile source and the sulfur contents in fuel.

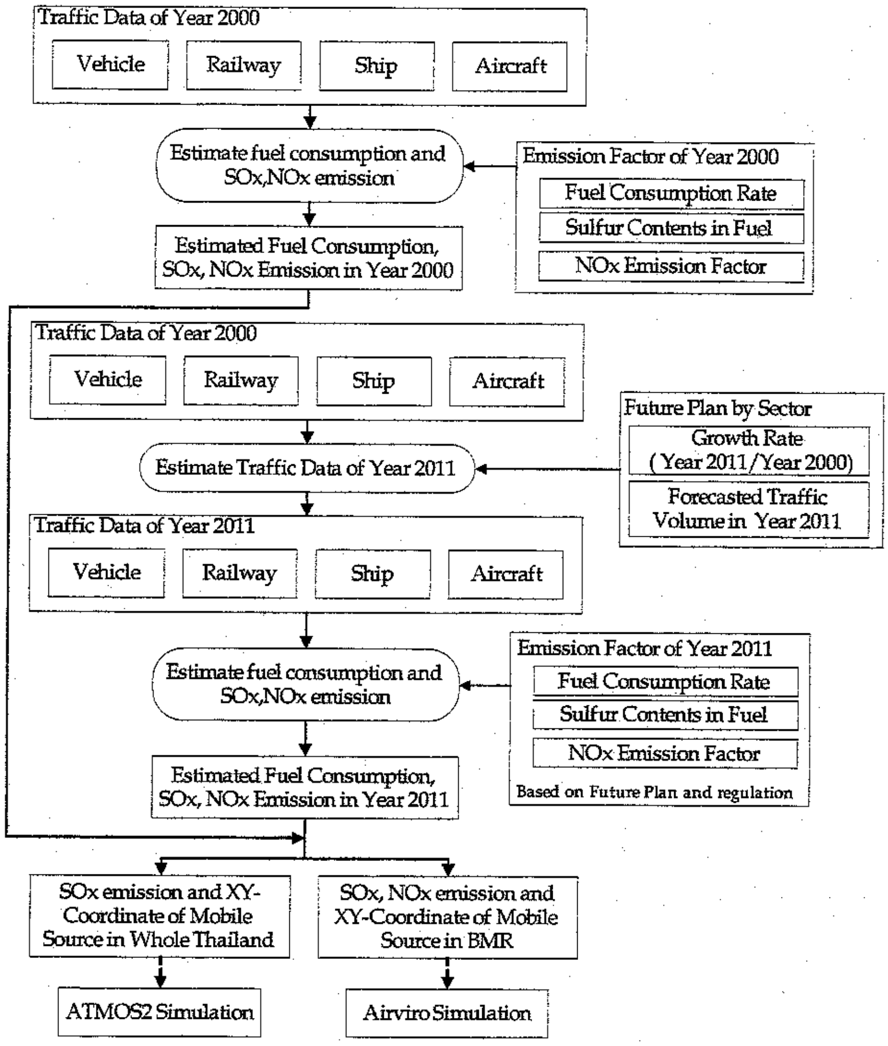

Figure 4.1.1.1 General Flow of Mobile Source Inventory Development in Year 2000

4.1.2 Target Type of Mobile Source

The types of mobile source are as follows;

- Vehicle
- Railway
- Ship
- Aircraft

4.1.3 Target Areas

The target areas are as follows;

- The whole Thailand, which means all areas excluding the BMR in Thailand
- The BMR which includes: Bangkok Metropolitan Area, Samut Prakan, Nonthaburi, Pathun Thani, Nakhon Pathom and Samut Sakhon.

4.1.4 Target years

The target years are as follows;

- The year 2000 as the base year
- The year 2011 as the target year

4.1.5 Target Pollutants

The target pollutants are as follows;

- In the whole Thailand
  - SOx (Sulfur Oxides)
- In the BMR
  - SOx (Sulfur Oxides)
  - NOx (Nitrogen Oxides)

4.2 Mobile Source Inventory of the Year 2000

4.2.1 Mobile Source Inventory of the Year 2000 in the Whole Thailand

4.2.1.1 Vehicles

1) <u>Outline</u>

The flow of SOx emission estimation of vehicles of the year 2000 in the whole Thailand is shown in Figure 4.2.1.1. In the SOx emission estimation of vehicles, two kinds of method are applied, which are for vehicles on main roads, minor roads, provincial roads, express ways and major Soi, and for traffic in local areas.

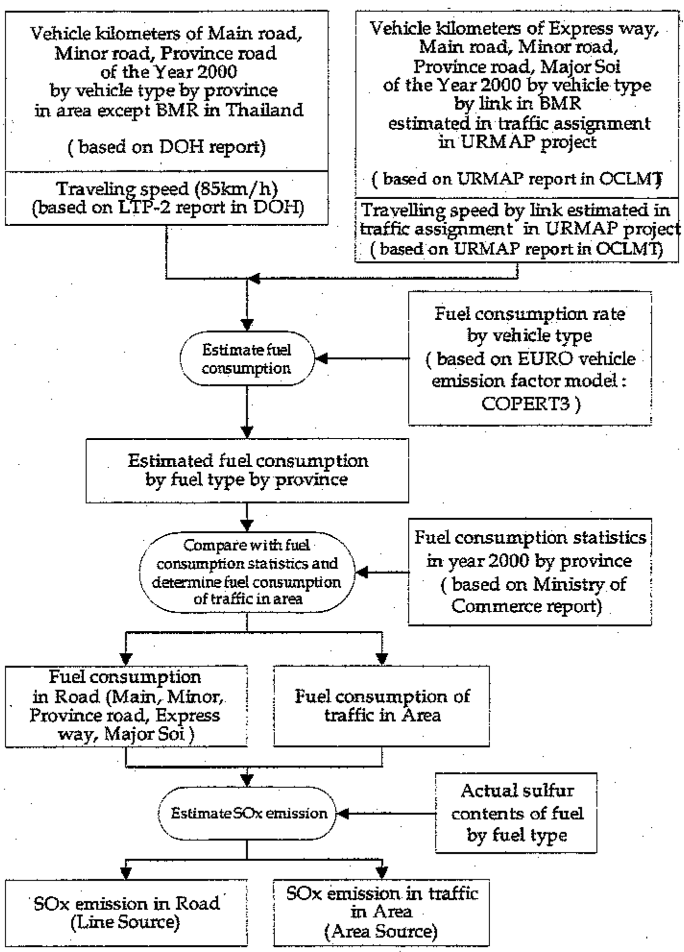

Figure 4.2.1.1 Flow of SOx emission estimation of vehicles of the Year 2000 in whole Thailand

The fuel consumption of road vehicles by province is estimated using the vehicle kilometers and fuel consumption rate of the vehicle based on the EURO vehicle emission factor model, COPERT3. In the area except the BMR, the vehicle kilometers of main roads, minor roads and provincial roads are applied. In the BMR, the vehicle kilometers of express ways and major Soi are applied in addition to the categories used in the area except the BMR.

By comparing the estimated fuel consumption of road vehicles with the statistics of fuel consumption, the fuel consumption of traffic in the local areas is determined.

The SOx emission of road and traffic in the local areas is estimated using the actual sulfur contents of fuel and the estimated fuel consumption.

2) Traffic Data

The vehicle kilometers of the year 2000 by vehicle type in the BMR are shown in Table 4.2.1.1, which are estimated using the Airviro database updated based on the traffic assignment data in "Urban Rail Transportation Master Plan (URMAP,2001) " report of OCMLT. The details of the updated Airviro database are explained in Chapter 6 "Model Simulation". The vehicle kilometers by vehicle type in the area except the BMR in Thailand are shown in Table 4.2.1.1, which are based on the DOH report.

The annual vehicle kilometers in the whole Thailand is about 161,000 million vehicle-kilometers in the year 2000. The share of the BMR is about 30%, 18% for the northeastern region and 17% for the northern region. The location of roads is shown in Figure 4.2.1.2.

Table 4.2.1.1 Vehicle Kilometers in Thailand in the Year 2000

Region	Vehicle Kilometers by vehicle type (Million Vehicle-Kilometers/year)					
	Car, taxi	light truck	Bus	heavy truck	Motor-cycle	total
BMR	23,859	7,058	3,228	4,794	7,086	46,025
Central Region	4,048	2,430	929	2,013	1,342	10,762
Northern Region	7,986	8,234	1,425	2,766	7,386	27,797
Northeastern Region	8,930	7,606	2,072	3,587	7,594	29,789
Southern Region	5,960	4,441	1,352	2,546	5,434	19,733
Eastern Region	5,322	4,265	1,096	2,287	2,281	15,251
Western Region	3,280	3,323	473	1,640	2,102	10,818
Total	59,385	37,357	10,575	19,633	33,225	160,175

Note: Car, taxi includes passenger car(gasoline and diesel) and taxi(gasoline)
Vehicle kilometer in the BMR is estimated based on traffic assignment data of the URMAP report in OCMLT.
Vehicle kilometers in other region except the BMR is based on "Highway Traffic Data by Province (2000), DOH".

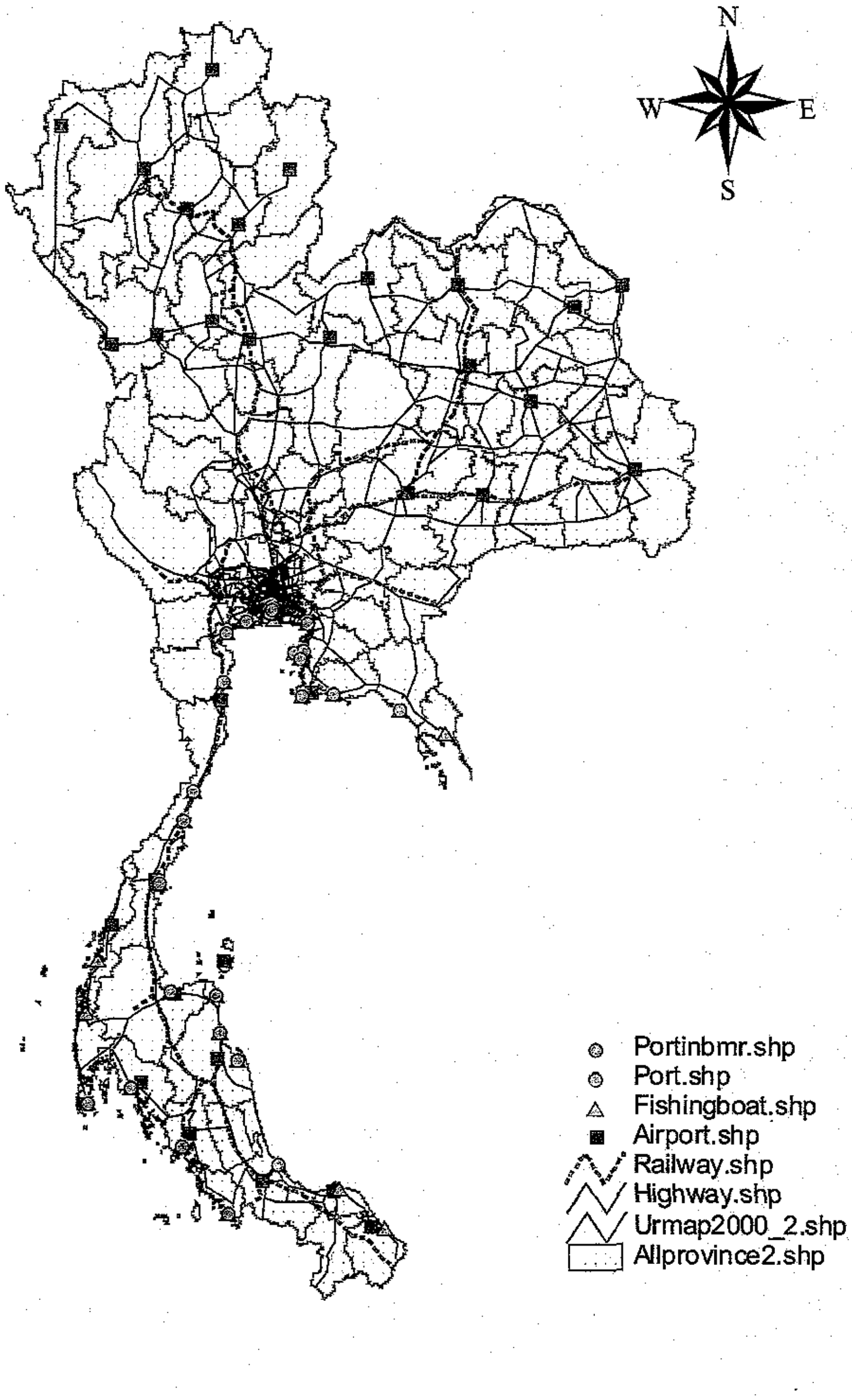

Figure 4.2.1.2 Location of Mobile Source of the Year 2000 in the Whole Thailand

3) Emission Factor

(1) Method

The emissions of SOx were estimated by assuming that all sulphur in the fuel was transformed completely into SOx and using the emission factors comprised of fuel consumption rate and actual sulphur contents in the fuel.

There may not have been any methods studied for calculation of fuel consumption rates, though some amounts of fuel consumption data of chassis dynamometer have been accumulated. In this study, Thai vehicles were considered to show similar tendency in the fuel consumption rate, to ones in the EU for the reason that all of the vehicle emission standards in Thailand (except some of the recent standards for motorcycles) have been quoted from the EU and all Thai vehicles can be classified by the EU emission standards enforced at their model years. In the EU, COPERT 3 (Computer Program to Calculate Emissions from Road Transport) is adopted officially as the vehicle emission calculation program, in which speed-dependent fuel consumption rates are provided for 6 vehicle and motorcycle types (divided into 21 detailed categories) under different emission standards (from pre-regulation to the latest-proposed standards). Thus, following on from what has been mentioned above, COPERT 3 was considered as the appropriate method for this study.

Figure 4.2.1.3 shows the general workflow of the SOx emission factor calculation, where fuel consumption rates provided as default values in COPERT 3 were combined properly by vehicle type after validity checks with test data, and converted to the emission factors with fleet data and actual sulphur contents in the fuel.

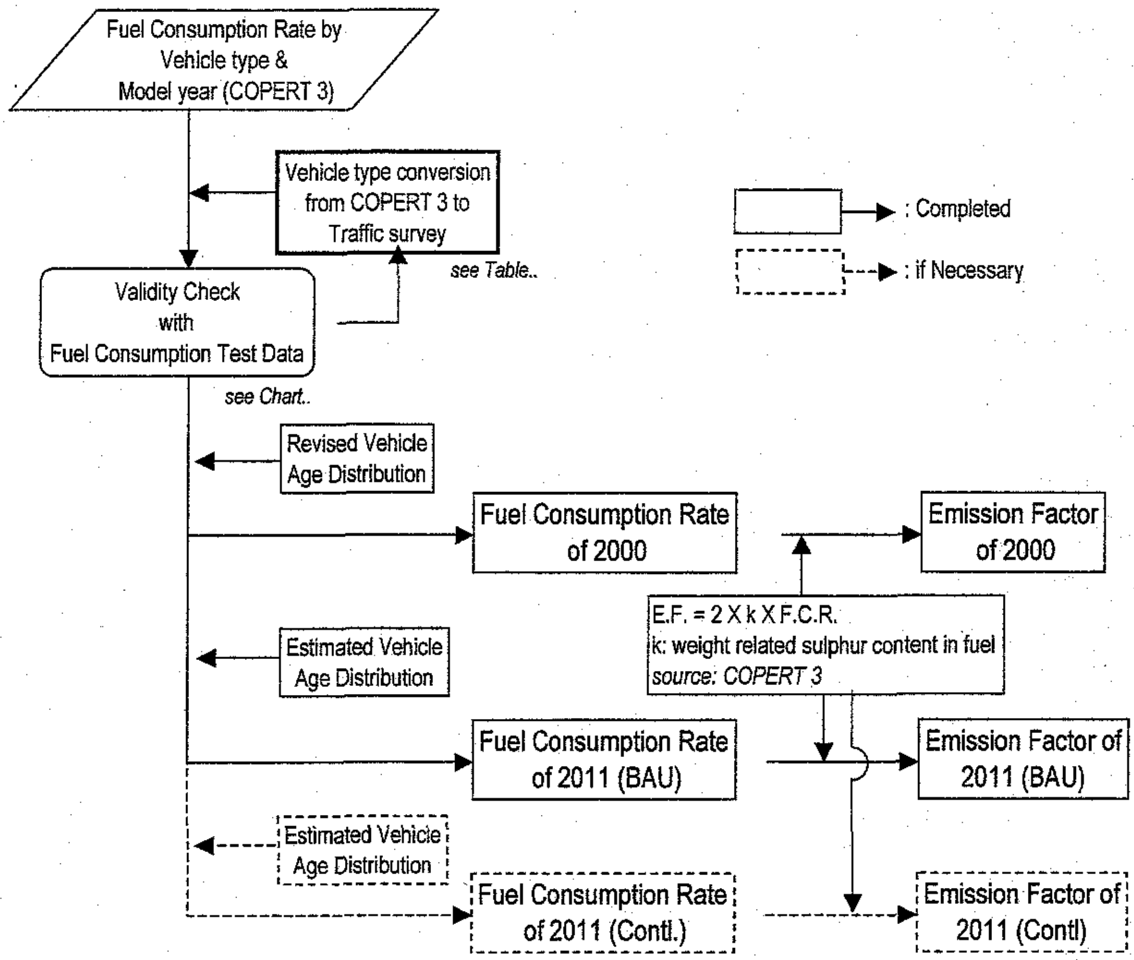

Figure 4.2.1.3 General Workflow of SOx Emission Factor Calculation

Table 4.2.1.2 shows the enforcement years of emission standards for each vehicle type. The fuel consumption rates for one vehicle type differ among different emission standards enforced, so that they need to be consolidated into a specific value of year 2000 with fleet data.

Table 4.2.1.2 Emission Standard Enforcement Year

	model year	LDGV	Taxi	LDDV	LDDT	HDDV	MC
	1976	Pre	Pre	Pre	Pre	Pre	Pre
	1977	Pre	Pre	Pre	Pre	Pre	Pre
	1978	Pre	Pre	Pre	Pre	Pre	Pre
	1979	Pre	Pre	Pre	Pre	Pre	Pre
For 2000	1980	Pre	Pre	Pre	Pre	Pre	Pre
	1981	Pre	Pre	Pre	Pre	Pre	Pre
	1982	Pre	Pre	Pre	Pre	Pre	Pre
	1983	Pre	Pre	Pre	Pre	Pre	Pre
	1984	Pre	Pre	Pre	Pre	Pre	Pre
	1985	Pre	Pre	Pre	Pre	Pre	Pre
	1986	Pre	Pre	Pre	Pre	Pre	Pre
	1987	Pre	Pre	Pre	Pre	Pre	Pre
	1988	Pre	Pre	Pre	Pre	Pre	Pre
	1989	Pre	Pre	Pre	Pre	Pre	Pre
	1990	Pre	Pre	Pre	Pre	Pre	Pre
	1991	Pre	Pre	Pre	Pre	Pre	Pre
	1992	Pre	Pre	Pre	Pre	Pre	Pre
	1993	Pre	Pre	Pre	Pre	Pre	Lv. 1
	1994	Pre	Pre	Pre	Pre	Pre	Lv. 1
	1995	ECE R83-B	ECE R83-B	ECE R83-C	ECE R83-C	Pre	Lv. 2
	1996	EURO 1	EURO 1	EURO 1	ECE R83-C	Pre	Lv. 2
	1997	EURO 1	EURO 1	EURO 1	EURO 1	Pre	Lv. 3
	1998	EURO 1	EURO 1	EURO 1	EURO 1	EURO 1	Lv. 3
	1999	EURO 2	EURO 2	EURO 1	EURO 1	EURO 1	Lv. 3
	2000	EURO 2	EURO 2	EURO 1	EURO 1	EURO 2	Lv. 3
	2001	EURO 2	EURO 2	EURO 2	EURO 2	EURO 2	Lv. 4
	2002	EURO 2	EURO 2	EURO 2	EURO 2	EURO 2	Lv. 4
	2003	EURO 2	EURO 2	EURO 2	EURO 2	EURO 2	Lv. 4
	2004	EURO 3	EURO 3	EURO 3	EURO 3	EURO 2	Lv. 5
	2005	EURO 3	EURO 3	EURO 3	EURO 3	EURO 2	Lv. 5
	2006	EURO 3	EURO 3	EURO 3	EURO 3	EURO 3	Lv. 5
For 2011	2007	EURO 3	EURO 3	EURO 3	EURO 3	EURO 3	Lv. 5
	2008	EURO 3	EURO 3	EURO 3	EURO 3	EURO 3	Lv. 5
	2009	EURO 3	EURO 3	EURO 3	EURO 3	EURO 3	Lv. 5
	2010	EURO 3	EURO 3	EURO 3	EURO 3	EURO 3	Lv. 5
	2011	EURO 3	EURO 3	EURO 3	EURO 3	EURO 3	Lv. 5

Table 4.2.1.3 shows the vehicle type conversion from COPERT 3 to traffic data, which were discussed in the former section. Vehicle types in COPERT 3 are divided by the size of engine displacement or vehicle weight. For this conversion, some of them were combined with their weights based on the statistics, such as the production data of TAIA or the registered data of DLT, and some vehicle types were not considered due to their minority in the Thai market and their small impact on SOx emission, even though they are classified in COPERT 3.

BOX: Emission Standards of European Union

Thailand has adopted test cycles and emission standards conforming to ECE[1]/EEC[2] regulations for light-duty gasoline and light-duty and heavy-duty diesel vehicles. European emission regulations for on-road vehicles are broadly divided into for light-duty vehicles, and for heavy-duty diesel engines of trucks and buses.

Light-Duty Vehicles

For new light duty vehicles (cars and light commercial vehicles), emission standards were originally specified in the European Directive 70/220/EEC. Amendments to that regulation include the Euro 1/2 standards, covered under Directive 93/59/EC, and the most recent Euro 3/4 limits (2000/2005), covered by Directive 98/69/EC. Emission test cycle for these regulations is the ECE 15 + EUDC[3] procedure.

The EU light duty vehicle standards are different for diesel and petrol vehicles. Diesels have lower CO standards but are allowed higher NOx. Gasoline vehicles are exempted from PM standards.[4]

EU Emission Standards for Passenger Cars, g/km

Tier	year	CO	HC	HC+NOx	NOx	PM
Euro 1	1992	2.72	-	0.97	-	0.14
Euro 2 –IDI	1996	1.0	-	0.7	-	0.08
Euro2 – DI	1999	1.0	-	0.9	-	0.10
Euro 3 (G)	2000	2.30	0.20	-	0.15	-
Euro 3 (D)		0.64	-	0.56	0.50	0.05
Euro 4 (G)	2005	1.0	0.10	-	0.08	-
Euro 4 (D)		0.50	-	0.30	0.25	0.025

EU Emission Standards for Light Trucks, g/km

Tier	year	CO	HC	HC+NOx	NOx	PM
Euro 1 (G)	1994.10	2.72-6.90	-	0.97-1.70	-	-
Euro 1 (D)		2.72–6.90	-	0.97-1.70	-	0.14-0.25
Euro 2 (G)	1998.01	2.2-5.0	-	0.50-0.80	-	-
Euro 2 (D)		1.00-1.35	-	0.60-1.30	-	0.10-0.20
Euro 3 (G)	2000.01	2.3-5.22	0.20-0.29	-	0.15-0.21	-
Euro 3 (D)		0.64-0.95	-	0.56-0.86	0.50-0.78	0.05-0.10
Euro 4 (G)	2005.01	1.0-2.27	0.1-0.16	-	0.08-0.11	-
Euro 4 (D)		0.50-0.74	-	0.30-0.46	0.25-0.39	0.025-0.06

Note: Emission standard levels vary in accordance with the weight class.

Heavy-Duty Vehicles

The European regulations for new heavy-duty diesel engines are commonly referred to as Euro 1-5. The Euro 1 standards for medium and heavy-duty engines were introduced in 1992. The Euro 2 regulations came to power in 1996. These standards applied to both heavy-duty highway diesel engines and urban buses.

---

1 the United Nations Economic Commission for Europe
2 the European Economic Community
3 ECE 15 cycle is an urban driving cycle, also known as UDC and EUDC is an abbreviation for Extra Urban Driving Cycle.
4 http://www.dieselnet.com/standards/eu/ld.html

In 1999, the European Parliament and the Council of Environment Ministers adopted the final Euro 3 standard (Directive 1999/96/EC of December 13, 1999, amending the Heavy Duty Diesel emissions Directive 88/77/EEC) and also adopted Euro IV and V standards for the year 2005/2008.

In April 2001, the European Commission adopted Directive 2001/27/EC which introduced further amendments to Directive 88/77/EEC. The new Directive prohibits the use of emission "defeat devices" and "irrational" emission control strategies, which would be reducing the efficiency of emission control systems when vehicles operate under normal driving conditions to levels below those determined during the emission testing procedure.

It is expected that the emission limit values set for 2005 and 2008 will require all new diesel-powered heavy duty vehicles to be fitted with exhaust gas aftertreatment devices, such as particulate traps and DeNOx catalysts. The 2008 NOx standard will be reviewed by December 31, 2002 and either confirmed or modified, depending on the available emission control technology.

For the type approval of new vehicles with diesel engines according to the Euro 3 standard (year 2000), manufacturers have the choice between either of these tests. For type approval according to the Euro 4 (year 2005) limit values, the emissions have to be determined on both the ETC and the ESC/ELR tests.[1]

EU Emission Standards for Heavy-Duty Diesel Engines, g/kWh (smoke in m^{-1})

Tier	year	Test Cycle	CO	HC	NOx	PM	Smoke
Euro 1	1992	ECE R-49	4.5	1.1	8.0	0.36	-
Euro 2	1998.10		4.0	1.1	7.0	0.15	-
Euro 3	2000.10	ECS* & ELR**	2.1	0.66	5.0	0.10	0.8
		ETC***	5.45	0.78	5.0	0.16	-
Euro 4	2005.10	ECS & ELR	1.5	0.46	3.5	0.02	0.5
		ETC	4.0	0.55	3.5	0.03	-
Euro 5	2008.10	ECS & ELR	1.5	0.46	2.0	0.02	0.5
		ETC	4.0	0.55	2.0	0.03	-

ECS*: European Stationary Cycle
ELR**: European Load Response
ETC***: European Transient Cycle

[1] http://www.dieselnet.com/standards/eu/hd.html

Table 4.2.1.3 Vehicle Type Conversion from COPERT 3 to Traffic Data

Vehicle Type of COPERT 3			Capacity	Equivalent Vehicle Type of Traffic Data	
1	Passenger Cars	Gasoline <1.4 l	---	Car	
		Gasoline 1.4 - 2.0 l	---	Car + Taxi	- Displacement Share
		Gasoline >2.0 l	---	Car	from Vehicle Production Data of TAIA
		Diesel <2.0 l	---	*negligible*	- Gasoline/Diesel Ratio*
		Diesel >2.0 l	---	Car	- Taxi share of Gasoline P.C.
		LPG	---	*negligible*	from Registered Vehicle Data of DLT
2	Light Duty Vehicles	Gasoline <3.5 t	<1.5 t	*negligible*	
		Diesel <3.5 t	<1.5 t	Light Truck (Pick-up)	
3	Heavy Duty Vehicles	Gasoline >3.5 t	1.5 t<	*negligible*	
		Diesel 3.5 - 7.5 t	1.5 - 4.5 t	Medium Truck	- Displacement Share
		Diesel 7.5 - 16 t	4.5 - 9.0 t	Medium Truck	from Vehicle Production Data of TAIA
		Diesel 16 - 32 t	9.0 - 20.0 t	Heavy Truck	- Displacement Share
		Diesel >32 t	20.0 t <	Heavy Truck	from Vehicle Production Data of TAIA
4	Buses	Urban Buses	---	Medium Bus	
		Coaches	---	Heavy Bus	
5	Motor-cycles	2-str. <50 cc	---	*negligible*	
		2-str. >50 cc	---	Motorcycle	- 2/4- str. Ratio
		4-str. <250 cc	---	Motorcycle	from Vehicle Production Data of TAIA
		4-str. 250 - 750 cc	---	Motorcycle	- Displacement Share
		4-str. >750 cc	---	Motorcycle	divided equally

Note: TAIA (The Thai Automotive Industry Association), DLT (Department of Land Transport)

Vehicle Type Definition for COPERT 3		
1	Passenger Cars	4-wheeler for passenger with Max. capacity <= 8 persons except driver
2	Light Duty Vehicles	4-wheeler for freight and Gross Vehicle Mass < 3.5t
3	Heavy Duty Vehicles	4-wheeler for freight and Gross Vehicle Mass > 3.5t
4	Buses	4-wheeler for passenger with Max. capacity > 8 persons except driver
5	Motorcycles	2-wheeler

Vehicle Type Definition for Traffic Data of Thailand		
1	Car & Taxi	Passenger Car
		Taxi
2	Light Truck (Pick-up)	4 wheels
3	Medium Truck	>= 6 wheels
4	Heavy Truck	>= 10 wheels
5	Light Bus	Micro Bus, Green Bus
6	Heavy Bus	Urban Bus, Coach
(7)	Bicycle, Tricycle	---
8	MC & Samlor	2, 3 wheels

Note: Samlor (Tuk-tuk fueled by LPG) is considered neglisible for small LPG consumption.

The share of LDGV/LDDV is shown on the right.

Region		Year 2000	Year 2011
Whole Kingdom	LDGV	79.7%	85.1%
	LDDV	20.3%	14.9%
BMR	LDGV	80.7%	86.6%
	LDDV	19.3%	13.4%
Central_(sub)	LDGV	77.1%	84.2%
	LDDV	22.9%	15.8%
Eastern	LDGV	81.5%	85.3%
	LDDV	18.5%	14.7%
Western	LDGV	75.6%	82.2%
	LDDV	24.4%	17.8%
Northeastern	LDGV	67.9%	73.3%
	LDDV	32.1%	26.7%
Northern	LDGV	83.1%	86.2%
	LDDV	16.9%	13.8%
Southern	LDGV	86.8%	88.0%
	LDDV	13.2%	12.0%

(2) Fleet Data

Fleet data, comprised of age distribution and mileage distribution of the vehicle, were necessary for the compilation of emission factors provided by the model years. As for age distribution, the annual numbers of new registered vehicles by type collected from LTD were adopted and for the period without available data they were estimated by the high-correlated social index and the purchase of vehicles in private consumption expenditure. The annual number of vehicles registered was considered as the vehicle population of each age for 25 years disregarding the number of vehicles which retired during the 25 years.

Figure 4.2.1.4 shows the workflow of age distribution calculation and Figure 4.2.1.5 shows the sample correlation between the number of new registered vehicles and economic indicators, and age distributions for all vehicle types.

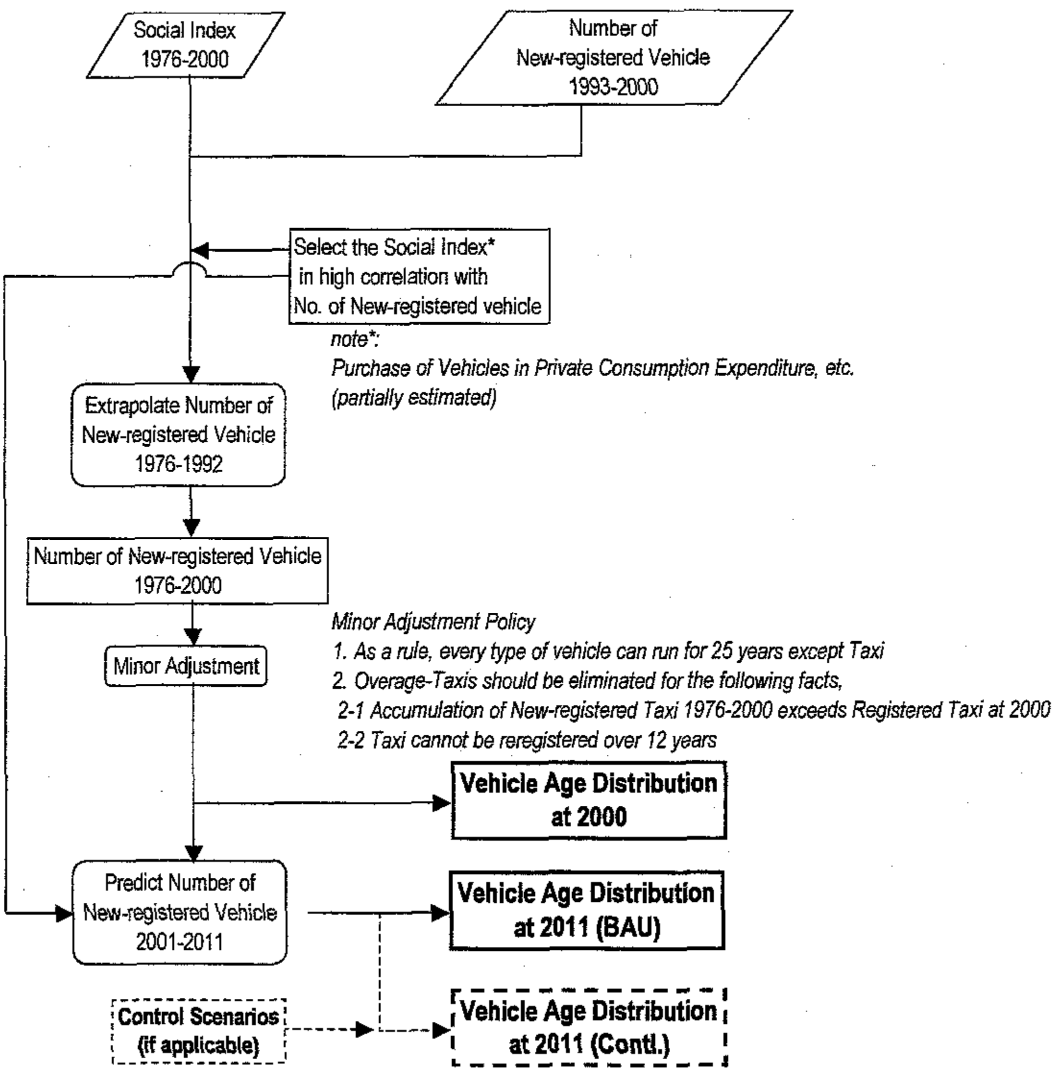

Figure 4.2.1.4 Workflow of Age Distribution Calculation

2000

age	year	LDGV	Taxi	LDDV	LDDT	HDDV	MC
1	2000	5.4%	6.4%	4.4%	5.6%	3.7%	5.2%
2	1999	3.9%	2.9%	2.7%	4.5%	2.5%	3.8%
3	1998	2.9%	5.2%	2.3%	3.5%	3.4%	4.1%
4	1997	9.0%	7.7%	7.8%	10.1%	10.0%	7.5%
5	1996	9.5%	10.6%	9.8%	14.2%	13.9%	9.5%
6	1995	8.8%	10.0%	10.4%	13.2%	12.3%	10.2%
7	1994	9.0%	14.4%	11.6%	10.6%	9.4%	8.3%
8	1993	8.2%	42.8%	16.0%	8.6%	8.1%	6.5%
9	1992	6.4%	0.0%	4.6%	7.8%	4.8%	6.3%
10	1991	4.5%	0.0%	3.0%	4.8%	3.2%	4.5%
11	1990	4.8%	0.0%	3.2%	5.3%	3.4%	4.8%
12	1989	3.6%	0.0%	2.4%	3.4%	2.6%	3.6%
13	1988	2.8%	0.0%	2.1%	2.1%	2.2%	2.9%
14	1987	1.9%	0.0%	1.7%	0.8%	1.8%	2.1%
15	1986	1.5%	0.0%	1.5%	0.1%	1.6%	1.7%
16	1985	1.5%	0.0%	1.5%	0.1%	1.6%	1.7%
17	1984	2.0%	0.0%	1.7%	0.8%	1.8%	2.1%
18	1983	2.1%	0.0%	1.8%	1.0%	1.8%	2.2%
19	1982	1.8%	0.0%	1.7%	0.6%	1.7%	2.0%
20	1981	1.7%	0.0%	1.6%	0.4%	1.7%	1.9%
21	1980	1.6%	0.0%	1.6%	0.3%	1.7%	1.8%
22	1979	1.7%	0.0%	1.6%	0.5%	1.7%	1.9%
23	1978	1.7%	0.0%	1.6%	0.5%	1.7%	1.9%
24	1977	1.7%	0.0%	1.6%	0.5%	1.7%	1.9%
25	1976	1.7%	0.0%	1.6%	0.5%	1.7%	1.9%
		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

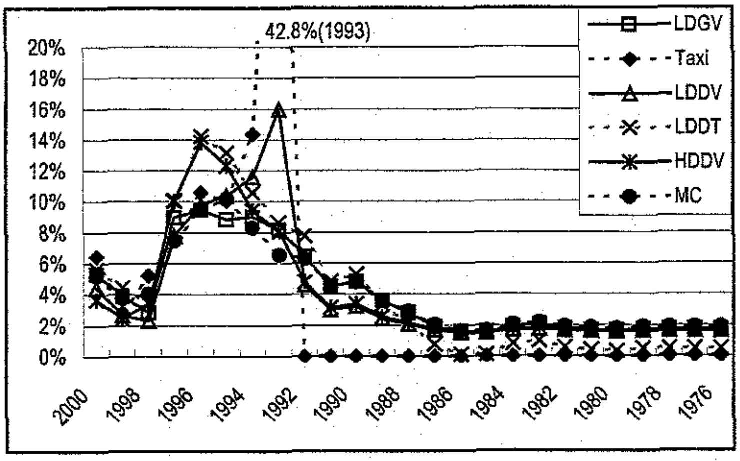

Figure 4.2.1.5 Age Distributions for the Year 2000

Mileage Distributions, assumed by PCD in 1994, were basically adopted in this study because of no available data elsewhere. However they were modified partly as follows,

- The mileages of MCs over 12 years were assumed to be one of 12 years old, since the accumulated number of new registered MCs from 1 (2000) to 12 (1989) years were far less than the total number of registered MCs in 2000 though PCD, in 1994, assumed MCs over 12 years should be retired already.
- The mileages of Taxis from 1976 to 1992 for the year 2000, and from 1987 to 1999 for the year 2011 were assumed as zero due to the minor adjustment policy discussed in 'Age Distribution'.

Table 4.2.1.4 and Figure 4.2.1.6 show the mileage distributions adopted.

Table 4.2.1.4 Mileage Distributions by Vehicle Type

(mile/year)

Age of Vehicle			LDGV	Taxi		LDDV	LDDT	HDDV	MC
			200/2011	2000	2011	200/2011	200/2011	200/2011	200/2011
1	(2000)	(2011)	12,755	12,755	12,755	12,755	20,140	18,211	4,786
2	(1999)	(2010)	12,698	12,698	12,698	12,698	17,572	16,767	4,475
3	(1998)	(2009)	12,409	12,409	12,409	12,409	15,432	15,437	4,164
4	(1997)	(2008)	12,387	12,387	12,387	12,387	13,639	14,213	3,853
5	(1996)	(2007)	12,481	12,481	12,481	12,481	12,133	13,086	3,543
6	(1995)	(2006)	12,288	12,288	12,288	12,288	10,863	12,048	3,232
7	(1994)	(2005)	12,288	12,288	12,288	12,288	9,788	11,093	2,921
8	(1993)	(2004)	11,749	11,749	11,749	11,749	8,877	10,213	2,611
9	(1992)	(2003)	11,742	0	11,742	11,742	8,103	9,403	2,300
10	(1991)	(2002)	11,469	0	11,469	11,469	7,444	8,657	1,989
11	(1990)	(2001)	11,469	0	11,469	11,469	6,883	7,971	1,678
12	(1989)	(2000)	11,469	0	11,469	11,469	6,405	7,339	1,368
13	(1988)	(1999)	11,059	0	0	11,059	5,999	6,757	1,368
14	(1987)	(1998)	11,074	0	0	11,074	5,655	6,221	1,368
15	(1986)	(1997)	11,111	0	0	11,111	5,365	5,728	1,368
16	(1985)	(1996)	10,587	0	0	10,587	5,123	5,273	1,368
17	(1984)	(1995)	11,059	0	0	11,059	4,924	4,855	1,368
18	(1983)	(1994)	10,814	0	0	10,814	4,763	4,470	1,368
19	(1982)	(1993)	10,513	0	0	10,513	4,637	4,116	1,368
20	(1981)	(1992)	10,000	0	0	10,000	4,543	3,789	1,368
21	(1980)	(1991)	10,000	0	0	10,000	4,500	3,800	1,368
22	(1979)	(1990)	10,000	0	0	10,000	4,500	3,800	1,368
23	(1978)	(1989)	10,000	0	0	10,000	4,500	3,800	1,368
24	(1977)	(1988)	10,000	0	0	10,000	4,500	3,800	1,368
25	(1976)	(1987)	10,000	0	0	10,000	4,500	3,800	1,368

Source: Motor Pollution Control in Bangkok Strategy for Progress, 1994, PCD

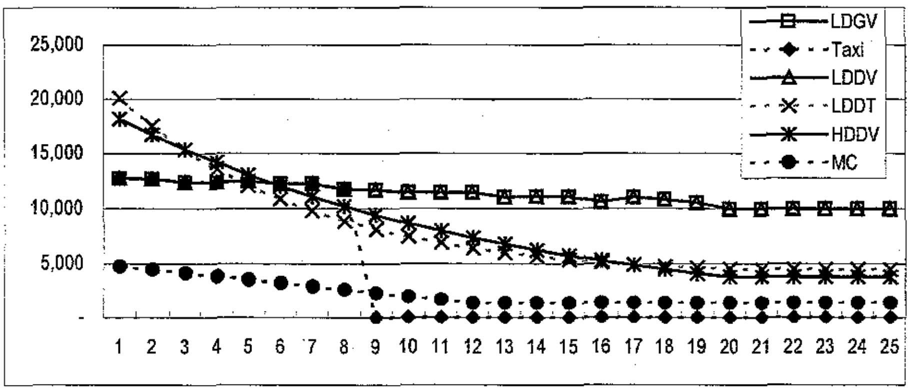

Figure 4.2.1.6 Mileage Distributions by Vehicle Type (2000)

(3) Emission Factor

Table 4.2.1.6 shows the emission factors of SOx, which were calculated from the fuel consumption rates which were complied with the fleet data shown in Figure 4.2.1.7 and the actual sulphur contents and specific gravity of fuel in Thailand shown in Table 4.2.1.5. In Figure 4.2.1.7, some ranges showed lower rates compared to the test data though the fuel consumption rate is within the range of the test data. However some of the test data adopted may be biased, so the fuel consumption rates should not be evaluated solely with them, as they are still under validation.

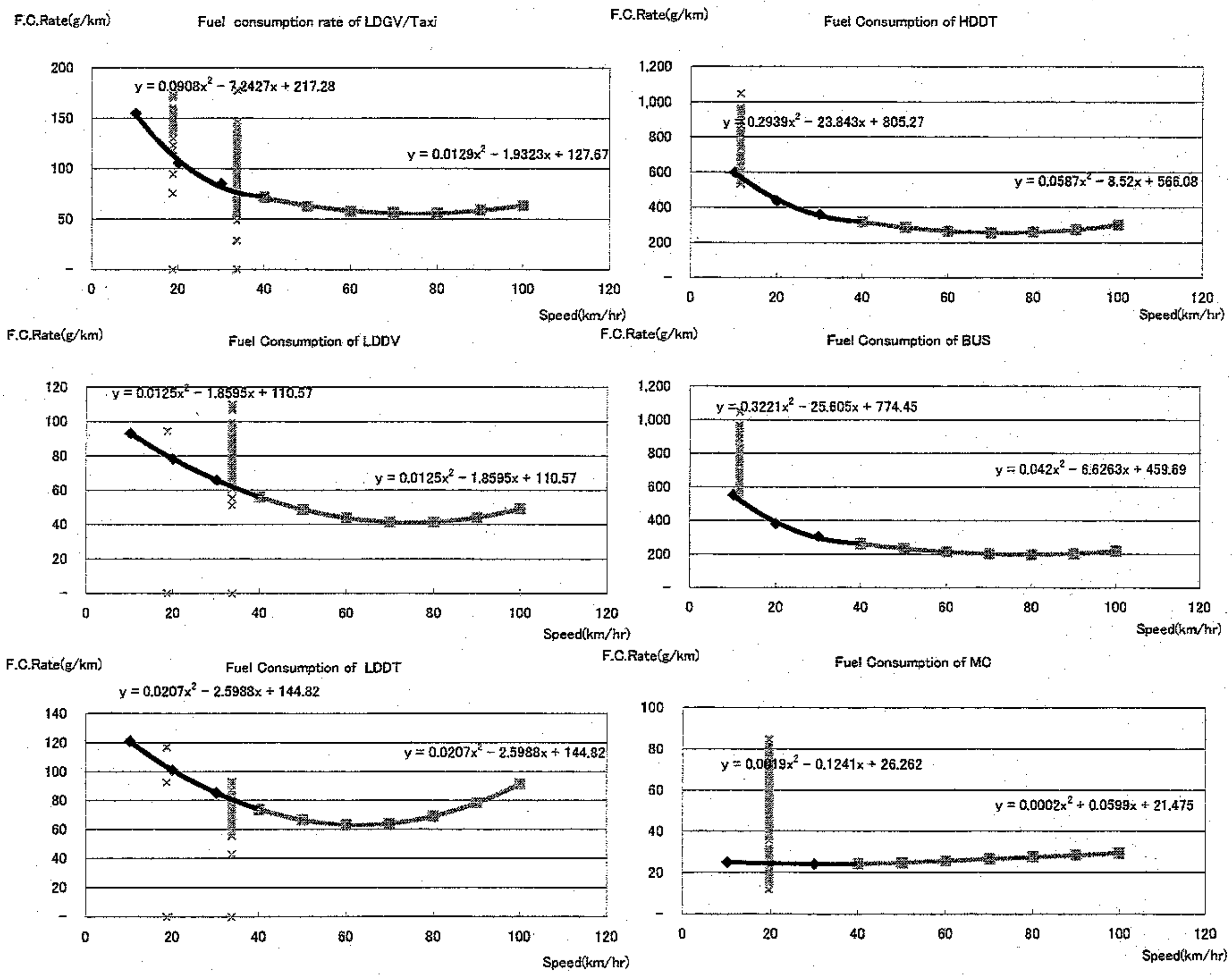

Figure 4.2.1.7 Fuel Consumption Rate by Vehicle Type

Table 4.2.1.5 Actual Sulphur Contents and Specific Gravity of Fuel

Fuel Type		Actual Contents (wt%)		Specific Gravity	
Gasoline		0.0382 (2000)	*1	0.7422	*2
Diesel	High speed	0.0348		0.8358	

Source: Sulfur contents in year 2000: from each refinery in Thailand (*1)
DCR, 2000 (*2)

The emission factors of SOx for the year 2000, specified for each speed range from 5 to 100 km/h, are shown in Table 4.2.1.6.

Table 4.2.1.6 Emission Factors of SOx

g/km

Target Year	Speed (km/h)	PS(G) LDGV	Taxi (G) Taxi (G)	PS(D) LDDV	L-Truck LDDT	Bus HDDV	H-Truck HDDT	MC MC
2000	5	0.14	0.14	0.07	0.09	0.34	0.36	0.02
	10	0.12	0.12	0.06	0.08	0.28	0.30	0.02
	15	0.10	0.10	0.06	0.07	0.24	0.26	0.02
	20	0.08	0.08	0.05	0.07	0.20	0.22	0.02
	25	0.07	0.07	0.05	0.06	0.17	0.19	0.02
	30	0.06	0.06	0.05	0.06	0.15	0.17	0.02
	35	0.06	0.06	0.04	0.05	0.14	0.16	0.02
	40	0.05	0.05	0.04	0.05	0.13	0.15	0.02
	45	0.05	0.05	0.04	0.05	0.12	0.15	0.02
	50	0.05	0.05	0.03	0.04	0.12	0.14	0.02
	55	0.05	0.05	0.03	0.04	0.11	0.14	0.02
	60	0.04	0.04	0.03	0.04	0.11	0.13	0.02
	65	0.04	0.04	0.03	0.04	0.11	0.13	0.02
	70	0.04	0.04	0.03	0.04	0.11	0.13	0.02
	75	0.04	0.04	0.03	0.04	0.11	0.13	0.02
	80	0.04	0.04	0.03	0.04	0.11	0.14	0.02
	85	0.04	0.04	0.03	0.05	0.11	0.14	0.02
	90	0.04	0.04	0.03	0.05	0.11	0.15	0.02
	95	0.05	0.05	0.03	0.06	0.12	0.16	0.02
	100	0.05	0.05	0.03	0.06	0.12	0.16	0.02

The equation to calculate emissions for vehicles is provided below.

SOx Emission(kg/year) = SOx emission factor(g/km/vehicle)
* Traffic volume(vehicle/day) * Distance (km) * 365 * 1/1,000

4) Estimated Emission

The estimated fuel consumption and SOx emission of vehicles of the year 2000 in the whole Thailand are shown in Table 4.2.1.7 and Figure 4.2.1.8, 4.2.1.9.

The fuel consumption and SOx emission of vehicles in the whole Thailand are about 14,400 kton/year, 10,300 ton/year in the year 2000 respectively.

The SOx emission of the BMR is the biggest and accounts for 35% of the vehicular SOx emission for the whole Thailand. More than about 60% of SOx is emitted from diesel vehicles and about 30% from gasoline vehicles. The SOx emission from traffic in local areas accounts for about 5%.

Table 4.2.1.7 Fuel Consumption and SOx Emission of Vehicles in the Year 2000

Region	Fuel Consumption (kton/year)				SOx Emission (ton/year)			
	Vehicle			Traffic in Area	Vehicle			Traffic in Area
	Gasoline	HSD	total		Gasoline	HSD	total	
BMR	1,865	2,617	4,482	495	1,425	1,822	3,247	377
Central	218	813	1,031	30	166	566	732	23
Northern Region	591	1,430	2,021	0	452	995	1,447	0
Northeastern Region	565	1,731	2,296	0	432	1,205	1,636	0
Southern Region	453	1,090	1,543	125	346	759	1,104	95
Eastern Region	316	1,008	1,324	89	241	701	943	67
Western Region	203	706	909	21	155	491	647	16
Total	4,211	9,395	13,605	759	3,217	6,539	9,756	578

Note: HSD:High Speed Diesel

Figure 4.2.1.8 Fuel Consumption of Vehicles in the Whole Thailand in the Year 2000

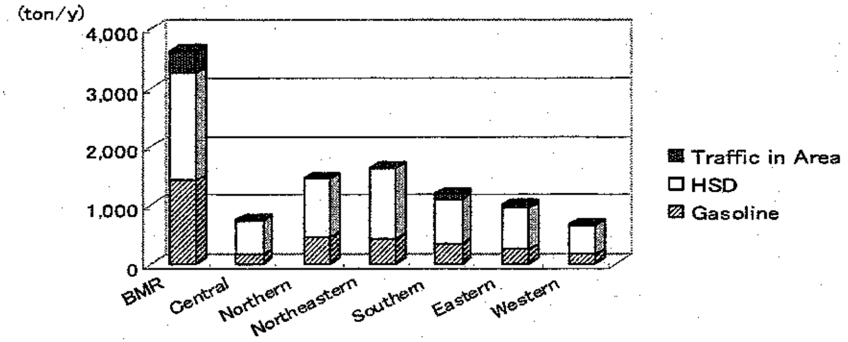

Figure 4.2.1.9 SOx Emission of Vehicles in the Whole Thailand in the Year 2000

4.2.1.2 Railways

1) Outline

The flow of the SOx emission estimation of railways for the year 2000 in the whole Thailand is shown in Figure 4.2.1.10.

The fuel consumption of railways by line and by province is estimated using the number of operations of trains based on the "Investment of Capacity Constraints and Determination of the Need for Track Doubling of SRT Network (2002) "report of the State Railway of Thailand (SRT) and the fuel consumption rate of trains based on the data of SRT. The lines include the North line, the Northeastern line, the Southern line, the Eastern line and others.

The estimated fuel consumption of railways is compared with the statistics of fuel consumption.

The SOx emission of railways is estimated using the actual sulfur contents of fuel and the estimated fuel consumption.

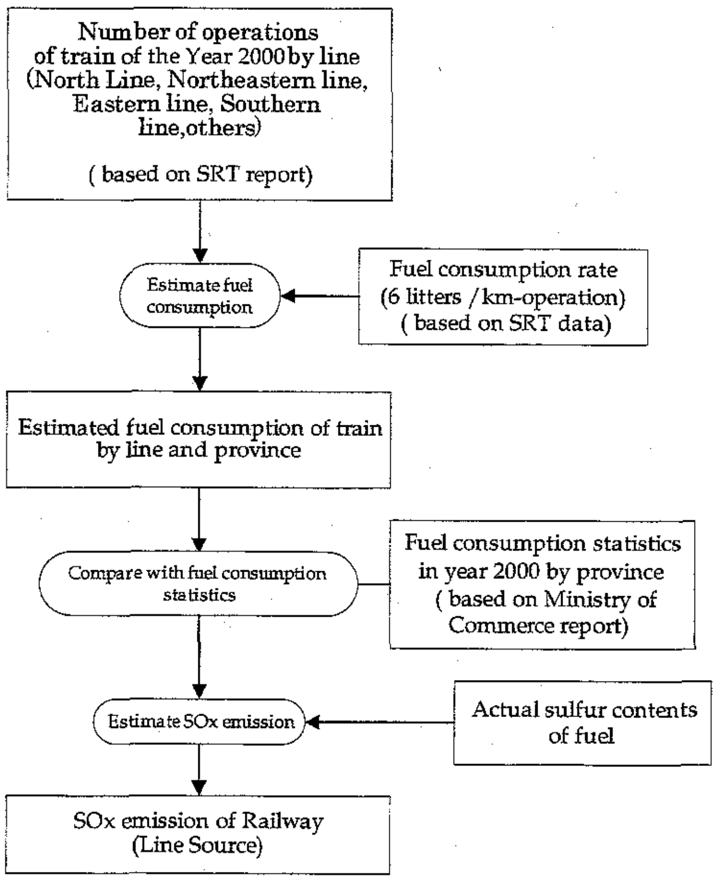

Figure 4.2.1.10 Flow of SOx emission estimation of railways for the Year 2000 in the whole Thailand

2) Traffic Data

The number of operations of trains on the 4 major lines (Northern line, Northeastern line, Southern line, Eastern line) and others for the year 2000 are shown in Table 4.2.1.8, which are based on the data of SRT. The location of the railway lines are shown in Figure 4.2.1.2.

Table 4.2.1.8 Number of Train Operations in the Year 2000

Line	Distance (km)	Operation (one-way/day)
Northern Line	780.25	879
Northeastern Line	1,090.77	302
Eastern Line	515.10	440
Southern Line	1,570.38	465
Mae Klong Line	64.66	42

Source: Investment of Capacity Constraints and Determination of the Need for Track Doubling of SRT Network (SRT, 2002)

3) Emission Factor

The fuel consumption rate and SOx emission factor of railways are shown in Table 4.2.1.9. The fuel consumption rate is based on the data of SRT. The actual sulfur contents in fuel is based on the data of the refinery and the specific gravity is based on the data of DCR.

Table 4.2.1.9 Fuel consumption rate and SOx emission factor

Items	Unit	Value		Note
Fuel consumption rate	Liter/km/operation	6.0	a	Based on SRT data
SOx emission factor	Kg/km/operation	0.0035	b	JICA Study Team estimated b = a * d * c /100 * 64/32
Sulfur contents in fuel	Wt%	0.0348	c	Data from each refinery in Thailand, 2000
Specific gravity of fuel	Kg/Liter	0.8358	d	DCR, 2000

Note: High speed diesel is used on railways.

The equation to calculate the emissions for railways is detailed below.

SOx Emission (kg/year) = SOx emission factor (kg/km/operation) * distance (km) * operation (operation/year)

Fuel Consumption (kg/year) = Fuel consumption rate (liter/km/operation) * distance (km) * operation (operation/year) * Specific gravity(kg/liter)

4) Estimated Emission

The estimated fuel consumption and SOx emission of railways for the year 2000 in the whole Thailand are shown in Table 4.2.1.10 and Figure 4.2.1.11. The fuel consumption and SOx emission of railways in the whole Thailand is about 242 kton/year, and 169 ton/year respectively.

The fuel consumption of the Northern and Southern Lines is the biggest and accounts for about 32% of the fuel consumption of railways in the whole Thailand. The share of the Northern and Southern Lines in SOx Emission is the same as their share in fuel consumption.

Table 4.2.1.10 Fuel Consumption and SOx Emission of Railways in the Year 2000

Line	Fuel Consumption (kton/year)	SOx Emission (tons/year)
Northern Line	77	54
Northeastern Line	61	42
Eastern Line	24	17
Southern Line	78	54
Mae Klong Line	2.4	1.7
Total	242	169

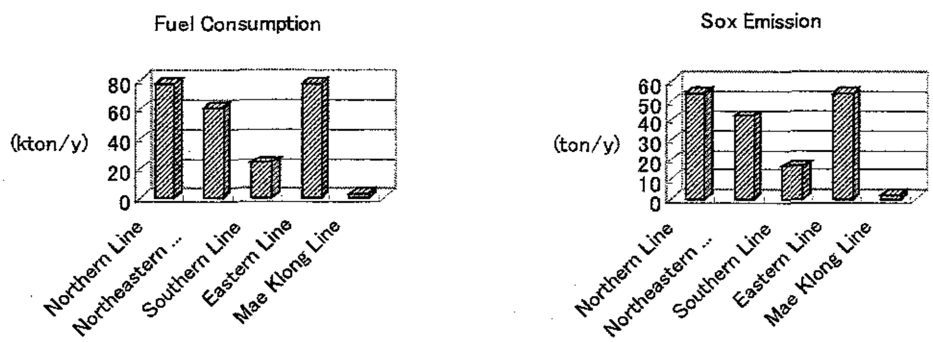

Figure 4.2.1.11 Fuel Consumption and SOx Emission of Railways in the Whole Thailand in the Year 2000

4.2.1.3 Ships

1) Outline

The flow of SOx emission estimation of ships for the year 2000 in the whole Thailand is shown in Figure 4.2.1.12.

In the SOx emission estimation, three kinds of method are applied, which are for vessels in port, for fishing boats and for small boats like express boats, ferry boats and long-tailed boats in the Chao Phraya River.

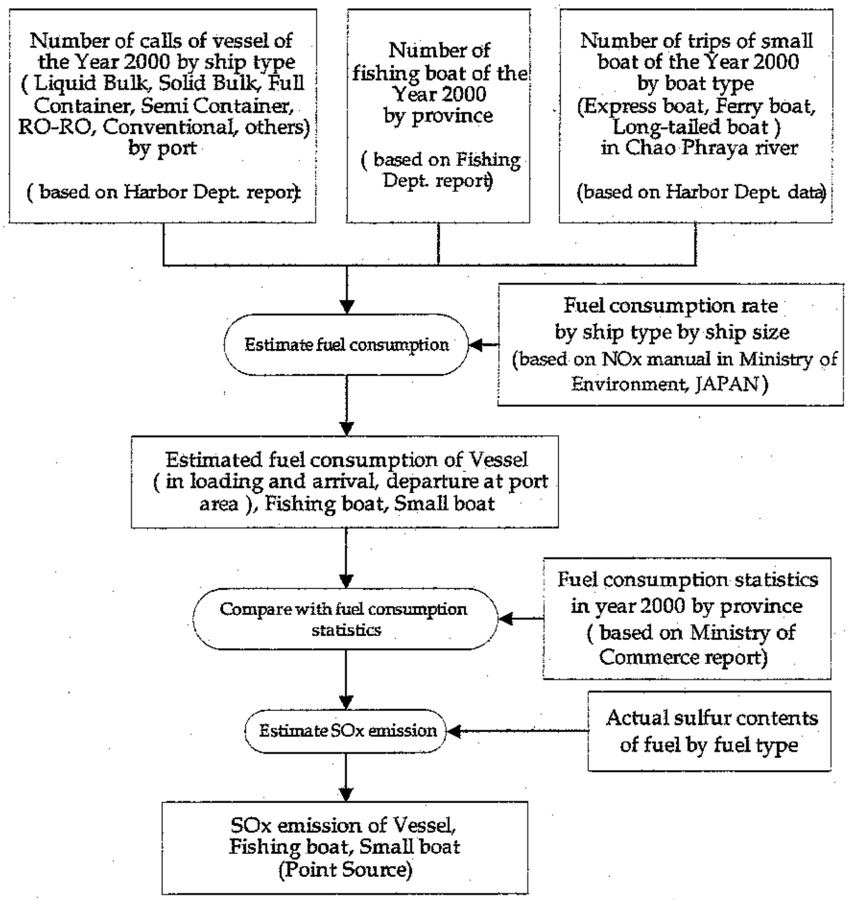

Figure 4.2.1.12 Flow of SOx emission estimation of ships for the Year 2000 in the whole Thailand

The fuel consumption of vessels in loading, arriving and departing is estimated using the number of calls of vessels by the ports and the fuel consumption rate based on NOx manual in Japan. In fishing boats, the fuel consumption is estimated using the number of fishing boats and the fuel consumption rate of the NOx manual. In small boats, the fuel consumption is estimated using the number of trips of express boats, ferry boats and long-tailed boats in the Chao Phraya River and the fuel consumption rate of the NOx manual. The fuel consumption of boats in other rivers such as the Tha Chin River is negligible because of the small number of trips.

The estimated fuel consumptions of vessels, fishing boats and small boats are compared with the statistics of the fuel consumption.

The SOx emissions of vessels, fishing boats and small boats are estimated using the actual sulfur contents of fuel and the estimated fuel consumption.

2) Traffic Data

The number of calls of vessels for the year 2000 by province in the whole Thailand is shown in Table 4.2.1.11, which is based on the "Thailand Shipping Statistics 2000". The number of calls of vessels for the whole Thailand was about 27,000 calls/year in the year 2000. The calls of vessels in the ports of Bangkok, Chon Buri and Rayong account for 34%, 26%, and 18% of the total calls of vessels in the whole Thailand respectively.

As for the fishing boats, the number of boats for the year 2000, which is referred to in "The 2000 Intercensal Survey of Marine Fishery", is shown in Table 4.2.1.12. The number of fishing boats in the whole Thailand is about 13,300 boats in the year 2000. The number of fishing boats in Songkhla and Trat account for 10%, 10% for the whole Thailand respectively.

The number of trips of small boats for the year 2000 in the Chao Phraya River is shown in Table 4.2.1.13, which is based on data of the Harbor Department.

The location of ports is shown in Figure 4.2.1.2.

Table 4.2.1.11 Number of Calls of Vessels on Arrival & Departure by Ship Type in the Year 2000

Unit: calls of vessel/year

Province	Liquid Bulk	Solid Bulk	Fully Cellular Container	Semi-Container	Ro-Ro	Conventional	Others	Total
Bangkok	973	1186	3,570	376	118	2,553	358	9,134
Samut Sakhon	12	73	0	0	0	22	234	341
Chachoengsao	350	1	9	1	0	174	76	611
Chanthaburi	0	0	0	0	0	0	1	1
Chon Buri	1,372	1036	1,265	254	311	2,573	127	6,938
Chumporn	0	0	0	0	0	2	0	2
Krabi	5	132	0	0	12	206	88	443
Nakhon Si Thammarat	84	59	0	2	0	114	40	299
Phetchaburi	0	0	0	0	0	1	0	1
Phuket	275	33	23	0	40	98	221	690
Prachuap Khiri Khan	0	72	0	0	0	261	11	344
Rayong	3,620	379	43	38	5	695	37	4,817
Satun	0	0	0	0	0	18	69	87
Songkhla	683	449	666	75	20	203	159	2,255
Surat Thani	0	0	0	0	0	1	0	1
Trang	1	285	0	0	0	51	688	1,025
Total	7,375	3,705	5,576	746	506	6,972	2,109	26,989

Source: "Thailand Shipping Statistics 2000 Ship Movement Series" (June 2001, Office of the Maritime Promotion Commission, Ministry of Transport and Communications)

Note: The number of calls shows the total sum of calls on arrival and departure.
Vessels in Samut prakan are included in Bangkok.
Ro-Ro : cargo ship for vehicles.

Table 4.2.1.12 Number of Fishing Boats in the Year 2000

Province	Number of Boats	Rated Power(PS)
Karabi	92	41
Chanthaburi	521	101
Chachoengsao	84	85
Chon Buri	751	61
Chumporn	925	97
Trang	321	142
Trat	1,342	83
Nakhon Si Thammarat	873	84
Narathiwat	48	61
Prachuap Khiri Khan	682	66
Pattani	577	96
Bangkok	0	0
Phangnga	141	126
Phetchaburi	589	99
Phuket	244	47
Ranong	225	87
Rayong	986	66
Songkhla	1,375	74
Satun	717	37
Samut Prakan	830	215
Samut Songkhram	662	147
Samut Sakhon	897	165
Surat Thani	381	142
Total	13,263	

Source:" The 2000 Intercensal Survey of Marine Fishery" (2000, Department of Fisheries Ministry of Agriculture and Cooperatives)

Table 4.2.1.13 Number of trips of Small Boats in the Chao Phraya River in the Year 2000

Type of small boat	Number of trips(trips/day)
Express boat	275
Ferry boat	4,344
Long-tailed boat	1,415

Source: Harbor Department

3) Emission Factor

The method to estimate the fuel consumption and SOx emission of vessels, fishing boats and small boats, which is based on the "NOx Manual (Ministry of Environment, Japan)", is shown below. The sulfur contents and specific gravity of fuel is shown in Table 4.2.1.19.

(1) Vessels in loading at ports

Emission for Sub Diesel Engines

- SOx Emission

$$S = W * s * 1/100 * 64/32$$

$$W = 0.17 * P^{0.98} * (A_1^{0.98} * T_1 * d_1 + A_2^{0.98} * T_2 * d_2)$$